E03749

CHARLES DARWIN'S STATUE
(IN THE UNIVERSITY MUSEUM, OXFORD)

A PICTURE BOOK
OF
EVOLUTION

ADAPTED FROM THE WORK OF THE LATE
DENNIS HIRD, M.A.

BY
SURGEON REAR-ADMIRAL
C. M. BEADNELL, C.B., K.H.P., M.R.C.S. (ENG.)
Late Fellow of the Chemical Society and of the
Royal Anthropological Institute

WITH A FOREWORD BY
SIR ARTHUR KEITH, M.D., D.Sc., LL.D., F.R.C.S., F.R.S.

LONDON:
WATTS & CO.,
5 & 6 JOHNSON'S COURT, FLEET STREET, E.C.4

FIRST EDITION (BY DENNIS HIRD): VOL. I, 1906; VOL. II, 1907.
SECOND EDITION (BY DENNIS HIRD): 1920.
THIRD EDITION (BY C. M. BEADNELL): 1932.

Printed and Published in Great Britain by
C. A. Watts & Co. Limited, 5 & 6 Johnson's Court, Fleet Street, London, E.C.4

FOREWORD

By Sir Arthur Keith, M.D., F.R.S.

MY friend Surgeon Rear-Admiral C. M. Beadnell has asked me to write the Foreword for this book. He is under the impression that my name is better known than his to the reading public. If this is so, then it is time that this impression should be altered. Naval surgeon by profession, Rear-Admiral Beadnell has been known to many of us for a long time as an able student of evolutionary problems. In bringing up to date, and indeed in rewriting, many chapters of the well-known work by the late Mr. Dennis Hird he has rendered a real service to the Cause of Evolution.

He and I believe in Evolution, not as a theoretical doctrine, but as a practical way of looking at all manifestations of life—of politics, of history, of all that pertains to the physical universe. The reader may ask: Is there anyone to-day who does not believe in Evolution? If readers will look into their real beliefs, they will probably find that, although they accept Darwinism as a truth, they think of it as a doctrine that was true in past times, but has in these modern days ceased to be operative. They are really not convinced evolutionists; they do not realize that the law of Evolution is going on in them and around them, shaping human destiny during every hour of the day. Most of us are willing to render Charles Darwin a lip service, but only few of us realize that every thought we formulate and every act we perform or fail to perform alter to an appreciable degree the course of events—the course which Evolution is taking in human affairs. We often boast of modern progress, forgetting that progress is in most cases merely another name for Evolution.

The main aim of this book is to bring home to·its readers that Evolution is not only a theoretical doctrine, but is also a practical issue. Hence the instances selected to illustrate the truth of Darwin's teaching have been chosen from common things—things with which all are familiar—in the streets, homes, and waysides of this goodly earth of ours and in the star-spangled heavens above. The examples chosen have been of a kind that permit the illustrator's art free scope, and help readers to understand how potent and prevailing is the law of Evolution. This book itself, in the form now given to it, has undergone a true evolutionary metamorphosis; Surgeon Beadnell has adapted it to meet modern needs, and has thus rendered a service to all—both young and old—who are interested in the Cause of Evolution.

ARTHUR KEITH.

PREFACE

By Compiler of Present Volume

ABOUT a quarter of a century ago the present writer was one of a London audience attending a course of Lantern Lectures upon the absorbingly interesting subject of Evolution delivered by that fascinating and popular lecturer, Dennis Hird, M.A., Principal of Ruskin College, Oxford. The appreciative reception, both in London and the provinces, accorded Mr. Hird's lectures made obvious the desirability of issuing them in book form. This was carried out by Messrs. Watts and Co., and the success of the first edition of Hird's *Picture Book of Evolution* soon rendered necessary the appearance of a second. As Mr. Hird died in 1920, a continued demand for the work has not, until the present issue, met with response. When Messrs. Watts asked me to undertake the task of revising the book, I confess to having had serious misgivings as to my competency to do so, in view of the enormous strides taken by Science in its several branches during the last two decades. Shortly after commencing the work it became apparent, both to the Publishers and myself, that revision in the ordinary sense was impracticable, and that if the book was to rank as an up-to-date illustrated statement of the ever-urgent message of Evolution it would have to be entirely recast. To such a degree has this had to be effected that the *Picture Book of Evolution* has now become not unlike that woodman's axe that was successively fitted with a new blade and a new haft. All the chapters have been re-written, and an Index, Appendices, and many modern pictures and illustrations have been added, though, wherever expedient, the pictures chosen by Mr. Hird have been retained. But the woodman's axe, despite its renewal, was still, in a sense, the old and trusty implement of its owner; and so likewise this book still preserves that individuality which was imparted to it by the hand of Dennis Hird.

I take this opportunity to exprcss thanks to the Publishers' Staff for much generous help in connection with the book.

Lastly I must mention my indebtedness to my wife for the constant assistance she has given me throughout in the checking of the proof-sheets and the preparation of the Index.

CHARLES M. BEADNELL.

Old Stacks, Ringwood, Hants.
May, 1932.

CONTENTS

PAGE

FOREWORD BY SIR ARTHUR KEITH, M.D., F.R.S. . v

PREFACE BY COMPILER OF PRESENT VOLUME . . vii

CHAP.

I. SIMPLE EXAMPLES 1

II. ASTRONOMY 19

III. GEOLOGY 58

IV. ZOOLOGY (TO MAMMALS) 87

V. MONKEYS AND MAN 114

VI. AN OUTLINE OF THE LAWS OF EVOLUTION . . 142

VII. DEVELOPMENT AND VARIATION 152

VIII. COMPARATIVE ANATOMY 168

IX. EMBRYOLOGY AND RUDIMENTS 196

X. PEDIGREE OF MAN 229

APPENDIX A 260

APPENDIX B 263

BOOKS RECOMMENDED 291

INDEX 297

A PICTURE BOOK OF EVOLUTION

CHAPTER ONE: SIMPLE EXAMPLES

IF we wish to know how the earth was formed, and how all the plants and animals came upon it, we must let the men of science teach us the wonderful things which they have found out. For thousands of years men have been inquiring into the history of the earth and all its inhabitants and they have discovered very marvellous things.

One of these discoverers was Charles Darwin. He and Alfred Russel Wallace separately discovered the same great underlying method of Evolution—Natural Selection. Darwin and Wallace published a short account of this in the journal of the Linnean Society on July 1, 1858; and Charles Darwin's famous book, *The Origin of Species*, appeared on November 24, 1859. Its publication has changed the thoughts of the world and killed many errors.

We are now able to look at the world and all "that therein is," and see pretty clearly how it has come to pass. The whole process is called Evolution, which means unrolling. With regard to plants and animals, Evolution teaches that they have come by descent from early forms which were so simple and tiny that they cannot properly be described as either the one or the other; they lived millions of years ago, before living things had divided into the two classes we call "plants" and "animals," each of which has developed on its own line.

In the history of our earth there is nothing more wonderful than the fact that man has discovered so many of the laws by which the earth and its inhabitants are governed. If we begin with quite simple cases, we shall be able to see for ourselves the working of some of these laws.

The acorn in Fig. 1 is of the kind from which grow our oak trees. If I were to ask anyone to bring a party of friends and sit under the shadow of this acorn, I should cause much laughter. But if we could wait 200 years, till the acorn had produced a full-grown oak, nothing would be more natural than to seek shelter under it on a warm summer day. This teaches us one of the great laws of the world—namely, the law of growth. There was a time when a very little child could carry the acorn and the germ within it; but after centuries of growth it becomes so large that the strongest animal in the world could not carry it. If we are to understand how all the living things in the world have come, we must always bear in mind this law of growth. The word "law" is used here and elsewhere throughout the work, not as implying the existence of a "law-maker" or "law-giver," but in the sense defined by Isaac Newton and Henri Poincaré, viz., as the necessary relation between the present state of the universe and its immediately antecedent and subsequent states.

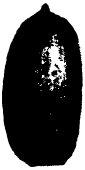


FIG. 1. An Acorn.

From a speck of matter so small that we cannot see it without a magnifying glass there may arise, by gradual growth, a giant tree or a huge animal. Let us take a familiar object—the bicycle—and we shall discover another law.

Fig. 2 shows us the nearest approach to a bicycle, such as was used in 1819. If men were to use it now we should laugh, for it seems so grotesque. The rider pushed the machine with his toes, and then rode as long as he could before he gave it another push.

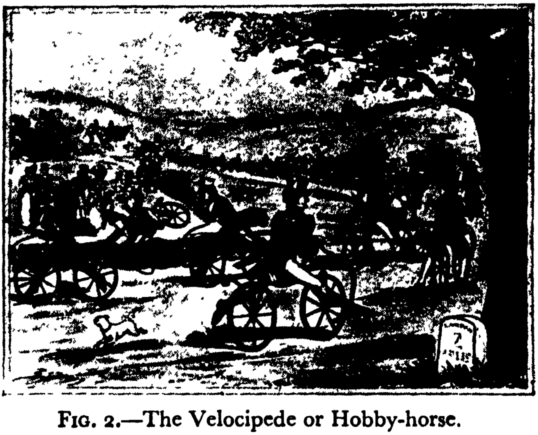


FIG. 2.—The Velocipede or Hobby-horse.

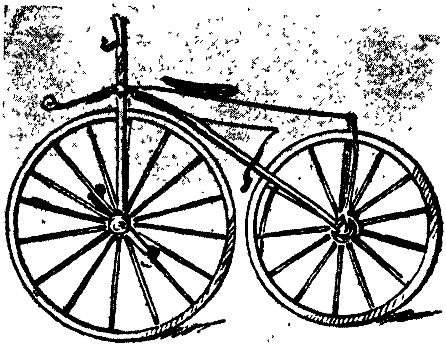


FIG. 3.—The "Bone-shaker."

But improvements were made, and nearly fifty years afterwards men used the old "bone-shaker," which you see in Fig. 3. It was an instrument of torture, without such luxuries as gearings or ball-bearings or pneumatic tyres; but it had pedals, and it was not a plaything. It was a great advance on the velocipede.

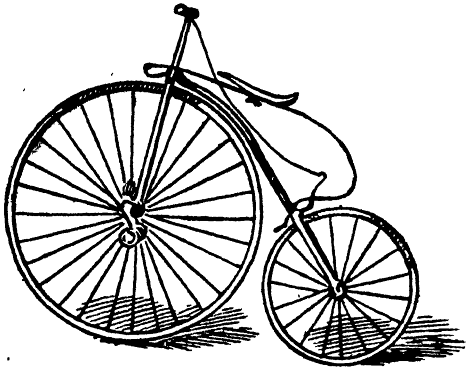


FIG. 4.—The Humber Spider.

After the bone-shaker had been in use a long time someone made an improvement, and men rode the "Humber Spider." This machine had an immense fore wheel, as you can see in Fig. 4, and a very small back wheel. The rider had to mount by steps, and to us it would seem not only a dangerous, but an absurd means of progression. Still, men had no better idea then.

But every year showed improvements. One found out that we need not have a huge wheel in front, with a sort of little lap-dog running behind; another thought of ball-bearings; another of the cushion tyre, and then of the pneumatic, and so on, till it was possible to buy a free-wheel, such as you see in Fig. 5, which not only is beautiful and comfortable, but saves a great deal of work whenever there is an incline.

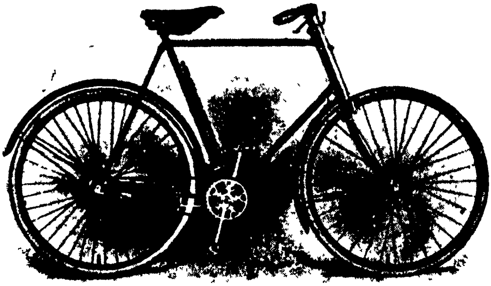
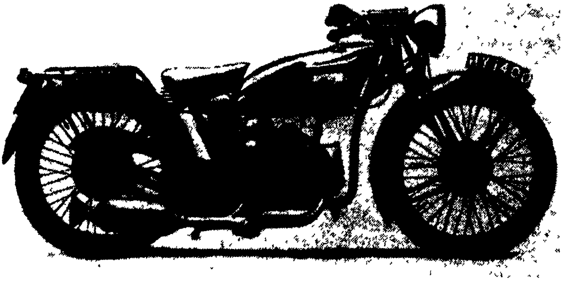


Fig. 5.—The Free-wheel.

Then the inventors caught up the idea of riding without toil, and produced motor-vehicles (Figs. 6 and 7).



The Motor Cycle

Fig. 6.—A Modern Motor-Cycle.

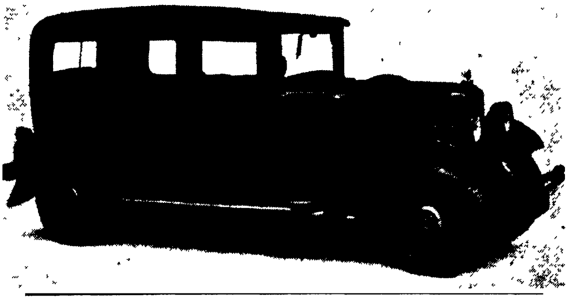


FIG. 7.—A Morris Oxford 6-cylinder Saloon.

The next great step was the conquest of the air by aeroplanes (Fig. 8).

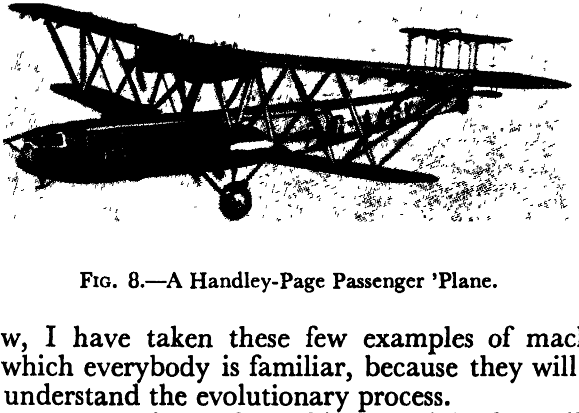


FIG. 8.—A Handley-Page Passenger 'Plane.

Now, I have taken these few examples of machines with which everybody is familiar, because they will help us to understand the evolutionary process.

The account given of the bicycle might be called a short history of its evolution. Some of the steps of this evolution are clear to us :—

1. The earliest form was so simple and rude as to be almost useless, so that form did not remain long.

2. The improved machines drove the others out of use. If you were to try to buy a "hobby-horse" or a "bone-shaker," you would soon learn that they are no longer in the market, and in most towns you would not find one at any price. The steady march of improvements has

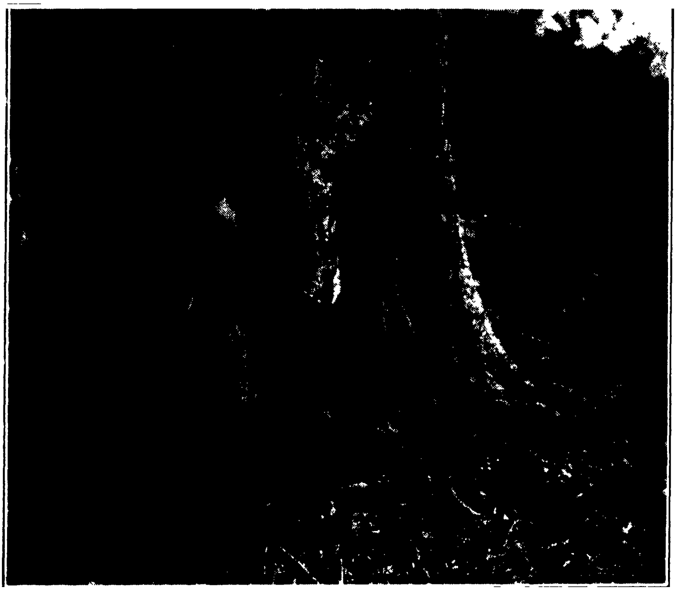


FIG. 9.—Veddas of Ceylon.

banished them. This is what we mean when we say that anything has become extinct. In a practical world the better banishes the inferior. It is indeed a form of " the survival of the fittest."

These two laws are of great importance, and we shall meet them again in considering Evolution.

After the very familiar steps shown by the bicycle and other means of transport, we may take another example.

In Fig. 9 we see a weapon which seems to us to belong so entirely to the past that it has left no trace in our modern life. Yet this is not so. Men lived many thousands of years before they discovered this deadly weapon. It was a marvellous discovery in its time, but you can find no soldiers armed with bows and arrows in any modern army.

The bow and arrow gave rise to two wonderful inventions of our modern life; we see them in Figs. 10 and 11.

Few people at first see any connection between a piano and a rifle. They constitute a fine example of two very different instruments having been developed from one.

Fig. 10.—A Chappell Grand.

When the hunter or warrior pulled the string close to his ear he heard a rich twang as the string vibrated. So he began to develop instruments for producing sound by arranging two or three strings in a simple way. For ages these were improved, as we have seen the bicycle was improved, till at last we have our modern piano—an arrangement of strings.

But a sterner use of the bow and arrow was to kill. Man is, unfortunately, a killing animal. He improved the arrow and added strength to his bow, till the English archers were the dread of their foes. Then the invention of gunpowder furnished a new force which propelled the missile independently of muscular labour. The earliest guns were simple, but constant improvements have given us the efficient modern rifle and Lewis gun. The steps of the evolution of the modern weapon can be seen in the Pitt Rivers Museum.

FIG. 11.

B.S.A. Short Lee-Enfield Mk. III.

Now, it must be granted that evolution has brought about modern bicycles, pianos, and rifles; yet the critic may ask: "Is there any such process in nature to be seen in the known history of living things?" There is.

We will take by way of illustration the feet of the horse, an animal whose evolution has been worked out with extraordinary detail by Marsh, Matthew, Lull, and others. All palæontologists (*palaios*, old; *onta*, existing things; *logos*, science) are agreed that the main drama of the horse's evolution was enacted in N. America, and yet, curiously enough, this animal became extinct throughout the whole of America in the middle of the Pleistocene period.[1]

The feet shown in Figs. 14 and 15 tell one of the most marvellous stories. The figures depict the celebrated fossil feet found by Professor Marsh in New Mexico and placed in the Yale Museum. (When any once-living thing has been preserved in the rocks it is called a *fossil*—a thing dug out.) The following deals principally with the fore-foot or "hand." Beginning at the bottom of Fig. 13, we will work our way upwards through the fossil-bearing layers and study the horse-like animals we meet *en route*.

The first definite horse-ancestor appears in the lower Eocene, and for that reason it has been christened *Eohippus* or dawn-horse (*eos*, dawn; *hippos*, horse). It was a small animal standing 12 inches high, about the size of a terrier. Its hand not only bore four perfect fingers, each ending in a little hoof or nail, but also the vestige of the thumb or first digit (1, Fig. 14). This shows that the creature sprang from a five-fingered stock. The foot carried but three toes, though the remnant of the little or fifth toe can be seen (v, Fig. 14) lying as a "splint-bone" against the side of the fourth. The first or great toe has altogether disappeared.

---

[1] See Fig. 53, Pillar of Rocks.

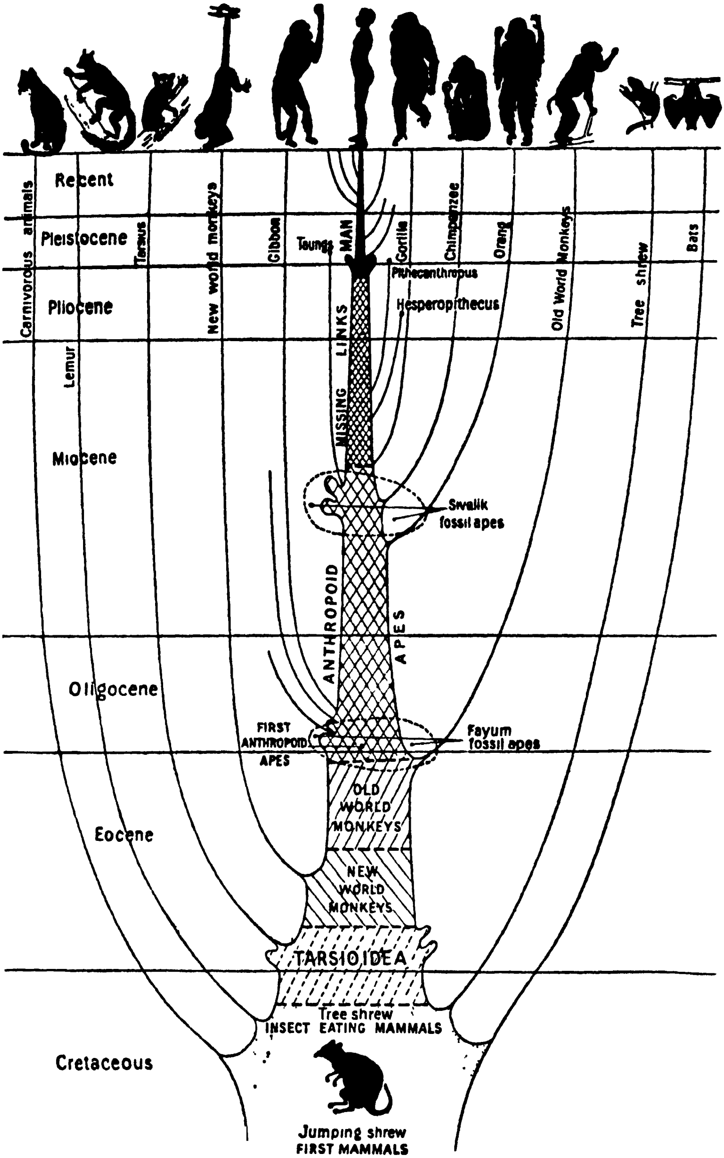


FIG. 12.—Man's Family Tree.

(From *Dorothy Davison's* "*Our Prehistoric Ancestors.*")

[NOTE.—Palæontologists no longer admit the existence of Hesperopithecus.]

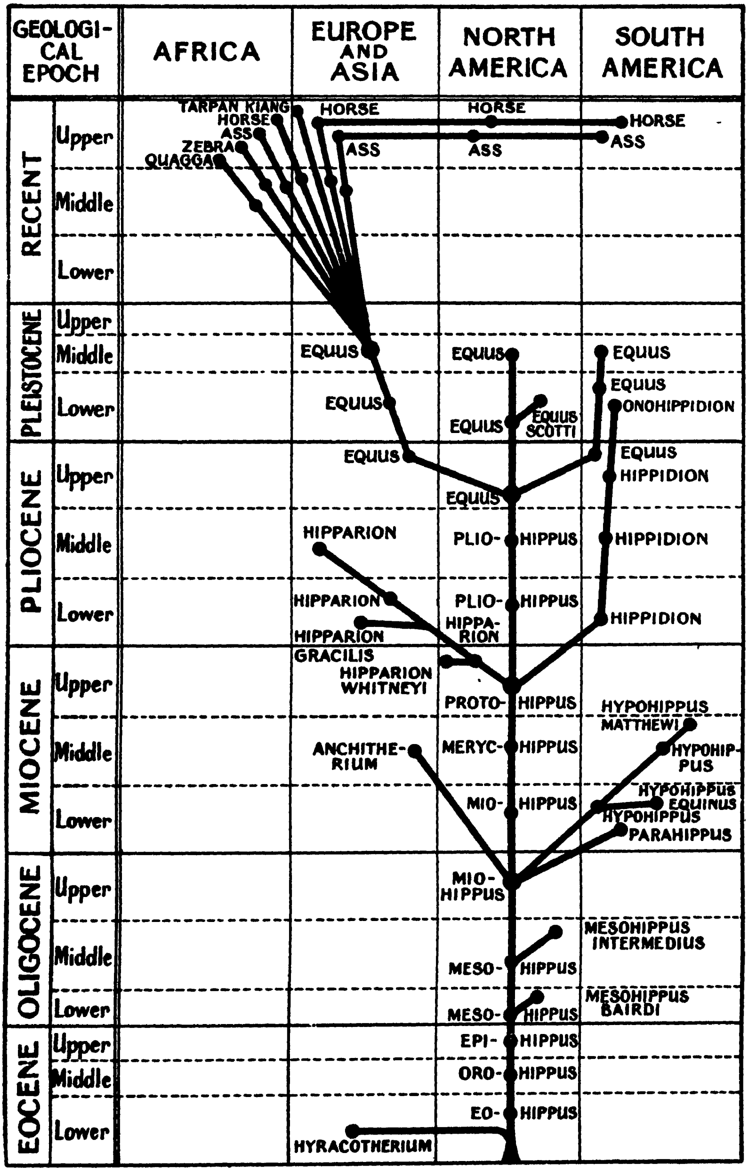


Fig. 13.—Evolution of the Horse and of its Relations and Ancestors. (After *Lull.*)

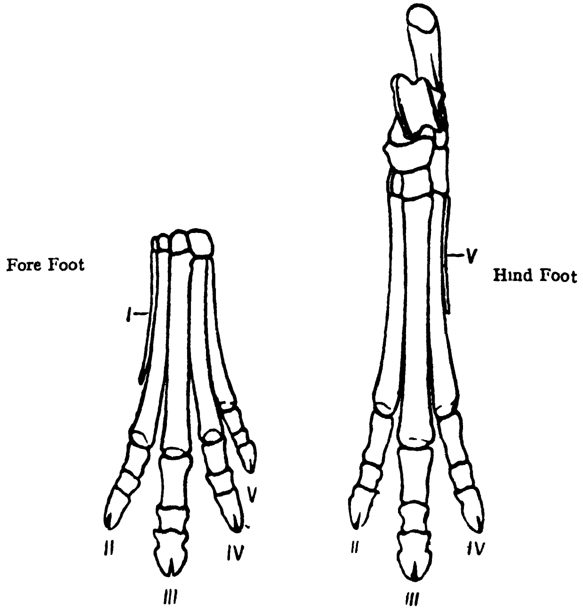


FIG. 14.—Foot of the Eohippus.

A close relation of this little animal, and not unlike it in appearance, dwelt at that time in Europe and Asia, its remains having been found in the London Clay layers. This animal, *Hyracotherium*, is the most primitive horse-like form of the Old World, and in all probability arose, as well as its cousin *Eohippus*, from some common ancestor of the Cretaceous no larger than a rat and bearing five digits on each limb.

Passing up into the middle Eocene, we come across a direct descendant of *Eohippus* called *Orohippus*, the Mountain horse, a slightly larger animal about 13½ inches high. This creature's superiority—from the specialized horse view-point—over predecessors is shown by the loss of the fifth toe and thumb and the shortening of the outer or little finger. *Orohippus* gave rise, in the upper Eocene, to *Epihippus*, which stood about 14 inches high; its hand still possessed four fingers and its foot three toes, but the middle digit of each showed signs of outgrowing all the others and of taking over, so to speak, their work.

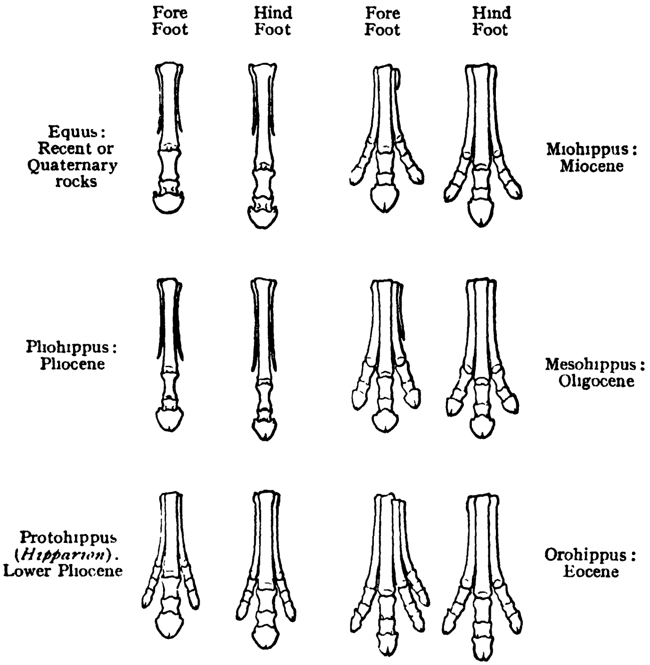


FIG. 15.—Six pairs of Horses' Feet.

From *Epihippus*, in the lower Oligocene, *Mesohippus* evolved, a creature that averaged the size of a retriever; *M. Bairdi* standing 18 inches, *M. intermedius* 24 inches high. It had three fingers and a splint-like vestige of the little finger. Although three toes were present in the foot, the animal's weight was now principally borne by the middle digit. In the upper Oligocene *Miohippus* had definitely evolved from and replaced *Mesohippus*; it had three toes and three fingers in hind and fore limbs respectively. You can see in the diagram a little knob of bone still clinging to the top of the outer or fourth finger, all that remains of the disappearing fifth digit. This animal, which, like its ancestors, dwelt in N. America, was slightly larger than its predecessor. It soon gave rise to four lines of descendants: (1) *Anchitherium*, which closely resembled *Miohippus*, wandered across to Europe and

Asia, but became extinct in the middle Miocene; (2) *Parahippus*, also very similar to its ancestor, migrated to S. America, where in early Miocene times it, too, became extinct; (3) *Hypohippus* wandered in the beginning of the Miocene to S. America, eking out an existence there until the middle of that period, when it suddenly vanished. This Forest horse possessed three toes in the foot and three fingers in the " hand," but vestiges, in the shape of small nodules of bone, of the thumb and little finger persisted. *H. equinus* stood 40 inches high, while the Nebraskan *H. Matthewi* was even taller. (4) The fourth line of descent, in the direct line towards modern horses, was represented in the middle Miocene by *Merychippus*.

Merychippus was three-digited in all limbs, though remnants of the fifth finger occasionally persisted. While *structurally* three-digited, *functionally* it was one-digited, as the side digits failed to reach the ground. From *Merychippus* arose, in the late Miocene, *Protohippus*, another three-digited horse.

From this latter sprang three branches: (1) *Hipparion*, which spread north to the Behring bridge and thence to Europe and Asia, where it became extinct in the mid-Pliocene. There were many varieties of this creature: *H. Whitneyi*, the Desert horse, kept to N. America and stood 40 inches high, while *H. gracilis*, standing 44 inches in height, got as far as Greece! (2) *Hippidion* was the S. American transmutation of *Protohippus*. It flourished throughout the Pliocene, and only became extinct in the Lower Pleistocene as a form called *Onohippidion*. Its mean stature was 49 inches, and it carried short, stout, one-toed feet and one-fingered " hands," both limbs bearing on each side of the now huge third or middle digit remains of the second and fourth ones. This *Hippidion* branch is of great interest in that it embodies the first one-fingered horse in S. America. How nearly *Onohippidion* was to gaining entrance into recent geological days is shown by the fact that its hoofs have been unearthed in Patagonian caves with the horny material in a fairly fresh state of preservation. (3) *Pliohippus*, in the direct line of descent, remained in N. America throughout the Pliocene, becoming, towards the end of that period, the first *Equus* or true horse with one-fingered fore and hind limbs. Remains of the second and fourth digits are still attached, as

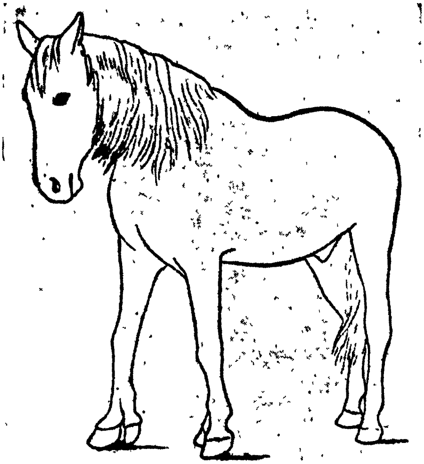


FIG. 16.—Horse with two divided hoofs.

splint-bones, to the long and sturdy middle digit or "cannon-bone."

This upper Pliocene N. American horse quickly gave rise to three branches: (1) One which went into the southern continent only to become extinct in the mid-Pleistocene; (2) another that remained in N. America, but also went the way of all flesh. Thus we have the remarkable state of affairs of an animal, after a long and laborious evolution in America, suddenly becoming extinct in the land of its birth while surviving in foreign parts. The cause of the extermination was probably some deadly parasite-inoculating insect similar to the Tsetse fly of modern equatorial Africa.

(3) The representatives of the third and successful branch of horse-ancestors went north and crossed over into Europe and Asia via the then Behring isthmus, in which countries they flourished throughout the Pleistocene and into modern times.

In the mid and upper Pleistocene the *Equus* of the Pliocene had broken up into several branches. One of these migrated to Africa, and by further subdivision gave rise to the African horse, ass, zebra, and quagga, the last of which only quite recently became extinct. Another branch remained in Eurasia and developed into the ass, tarpan, kiang (the only living wild equines) of the Gobi desert, and the modern horse, an animal standing 8½ hands or 34 inches (Shetland pony) to 18¼ hands or 73 inches (draught-horse). The last step in this wonderful equine drama took place when, a relatively few years ago, the Spanish Conquistadores imported a few horses into America. Some of these strayed from the settlements, ran wild, or became *feral* as it is termed, and spread rapidly until vast herds overran both continents, thudding their one-digited limbs over the fossils of their five-fingered ancestors. Such is the marvellous pedigree of man's most useful companion (Fig. 13).

Probably all horses are descended from an animal about the size of a rabbit. Fig. 14 should be placed at the bottom of Fig. 15 to complete the series so far as known at present. If you refer to the pillar of rocks, you will see the various layers in which all these fossil feet of the horse have been found.

We are so accustomed to the big hoof of the horse that we are apt to forget that this hoof is only the large overgrown nail of the middle finger. In several recent cases horses have had divided hoofs, as you see in Figs. 16 and 17.

These cases, together with the fact, to be considered later, that the very young foal, long before its birth, has three

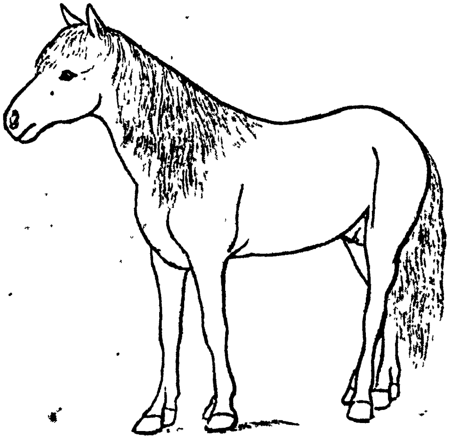


FIG. 17.—Horse with all its hoofs divided.

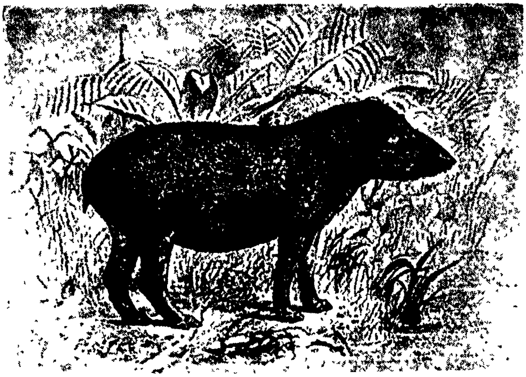


FIG. 18.—The Tapir.

toes, are further proofs that the horse has evolved from an ancestor which had, and used, more than one toe.

More light is thrown on its ancestry when we consider the order of animals to which the horse belongs. All hoofed animals are put together in one order, and are called *Ungulates* (this word comes from the Latin *unguis*, a finger-nail). Among Ungulates there are some remarkable forms, but the horse is the only animal that walks on *one* toe. One of the oldest of the order is the tapir, found in America, and shown in Fig. 18. It also contains the horse with one digit, the camel and giraffe with two, the rhinoceros with three, the pig, tapir, and hippopotamus with four, the hyrax with four fingers and three toes, and the elephant with five digits.

To realize that these large hoofed animals have come from smaller ancestors, you should study well the hyrax in Fig. 19. At the Cape they call it the dasee, and it is a common object on rocky hill-sides, emitting its plaintive cry and working its jaws about *as though it were chewing the cud.* It was, no doubt, this curious habit that led to the Scriptural description of these creatures as an "exceeding wise" though "feeble folk" that "chew the cud but divide not the hoof." That the little beast is "wise" may be true, for it is almost impossible to stalk or trap it, and its foot is not divided; but it does not chew the cud. Many people think it is a sort of rabbit, and no wonder; but the ears, as well as other marks, show it is not.

This little animal looks rather like an overgrown rat, or perhaps reminds you of a guinea-pig; but it is of amazing interest. For hundreds of thousands of years it has remained almost unchanged. It is the nearest living representative of the primitive ancestor of the elephant, the horse, the cow, and even the woolly mastodon. There are fourteen species of this animal still living. It is literally a walking museum; and perhaps only two *living* animals (the duck-mole and the sphenodon) are of equal interest.

Though its skeleton shows clearly the points of the hoofed-animal class, yet some of its teeth are like those of a rhinoceros, others like those of a rabbit or rat, and between these two extremes of teeth are some intermediate forms. The intestines of this animal tell a most ancient story, for it has paired cæca—*i.e.* two blind guts—and in this structure it resembles birds. When we remember that mammals diverged from reptiles before the birds did likewise, this structure, common to birds and dasees, carries us back into a lost period of life-history.

When any animal has points in common with many other animals of distinct groups, it is called a generalized form. This coney is a fine example of a generalized form, and it is most important that we should learn exactly what is meant by this term; for a generalized form gives rise to many varieties, and may be said to be the parent from which different species spring.

Generalized forms also usually become extinct, for they cannot hold their own in life's struggle. In this world

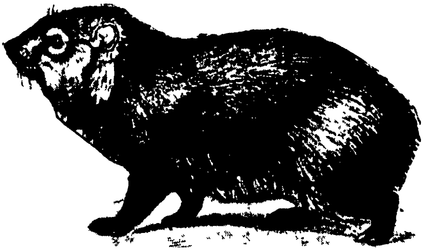


FIG. 19.—The Cape Hyrax or Dasee (a Coney).

it is sometimes the specialist that succeeds. The horse is a highly specialized form.

Now let us pause and see where we have got.

First, we have seen, from considering the acorn, that a small thing which a mouse can carry becomes, in the course of 200 to 400 years, so large as to shelter scores of people from the sun. All it needs is time to grow.

Second, we learnt from the bicycle that we get simple, imperfect forms first. We learnt the same thing in the development of the horse's foot. It began in the small animal with the generalized form, having five toes; but by specializing for thousands and thousands of years it threw off all but the middle toe, and became that most highly-developed animal, the horse, with one very large toe.

Third, we learnt also from the ancestors of the horse that small animals of a generalized form can give rise to many different kinds of large animals in the course of ages. Nothing can be plainer and nothing can be more wonderful than that the horse, elephant, camel, man, and many others have sprung from a group of very small animals, not unlike existing members of the *Soricidæ* or Shrews (Fig. 12).

Fourth, we saw, in the case of the rifle and the piano, which have both come from the old bow and arrow, that two most unlike things developing along different and diverging lines have yet evolved from a common source.

Now, these examples and these laws are noted merely to put us in the right attitude to consider a few of the millions of living things, and to observe the grandeur of an evolution which has required millions of years.

CHAPTER TWO: ASTRONOMY

MOST people have seen the stars on a clear night, but very few take the trouble to inquire what they are or what we know of them. Wise men studied them thousands of years before Evolution was discovered; and, though they are so many billions of miles away, we know a great deal about their history, nature, forms, and distances. Perhaps in no other department has man done so much as in astronomy.

The word " astronomy " is from two Greek words—*astron*, star, and *nemo*, distribute, and so the word means classing or arranging the stars. The Latin word for " star " is *stella*, so when we speak of the system of the stars we call it the stellar system.

As planets and satellites move round nearly in a circle, the path through which each body travels is called its orbit, which is from the Latin *orbis*, a circle. When a small body revolves round a larger it is called its satellite, from the Latin *satelles*, an attendant; thus the moon is the earth's satellite.

The Latin word for " sun " is *Sol*, so when we speak of the sun and all the bodies which revolve round him we call it the solar system.

There has been a regrettable tendency of late, even among eminent astronomers, to speak of " universes " in the plural and to separate what is called " our universe " from " distant universes." By the very implication of the word the universe includes our world and all the other worlds and bodies in space; it is from the Latin *universum*, the whole; and this Latin word is made up of two Latin words—*unus*, one, and *verto*, to turn. It is a most suitable word; it means all the worlds and bodies, and, as they are always going round, we may say they turn—the turning whole.

Now we want to learn how the stars and our world all came into their present state. Were they made just as they are, or do they change? Are some young and some old? In a word, have they evolved from some other form of matter, and are they still evolving?

Before we can look for laws and their lessons we must refresh our memories by an outline of the facts of that part of the universe which is best known to us. In other words, we must try and be clear about the solar system.

The solar system includes the sun, with those planets, satellites, and smaller bodies which revolve round the sun. The stellar system includes the solar system and all the stars and other bodies which can be seen and discovered by man. Our solar system is only a small speck in the great stellar system.

For the sake of clearness we will begin with the smaller first.

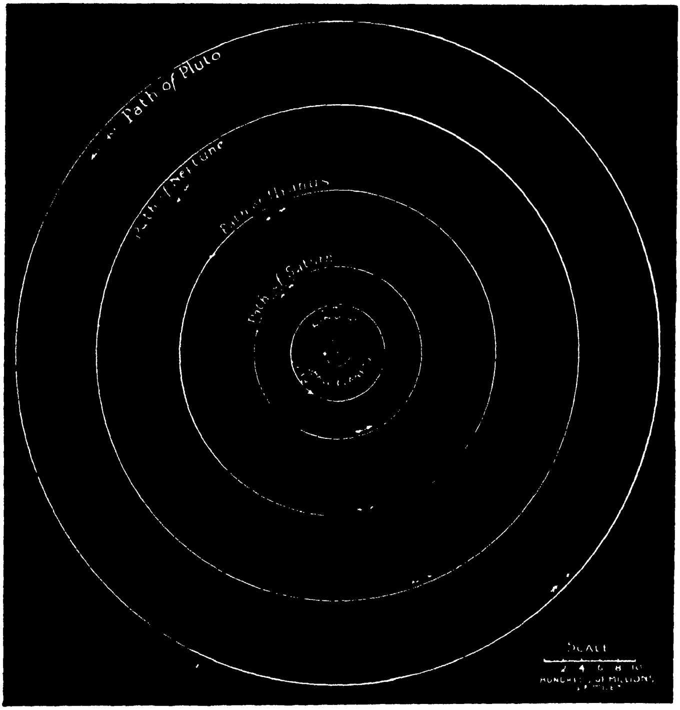


Fig. 20.—The Solar System.

Fig. 22 tells its own story. In the centre of all a bright body represents the sun. The circles show the orbits, or paths, in which the planets revolve. Their sizes are various; the distances incomprehensible. It seems to us a measureless space; it is, in reality, a small compartment in the infinite world of stars.

Note the distance of the earth, which is the third body from the sun. It seems quite near the sun, but it is nearly ninety-three million miles away. If this conveys any meaning, you may try to form some idea of the distance of the farther planets.

There are nine principal planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and the

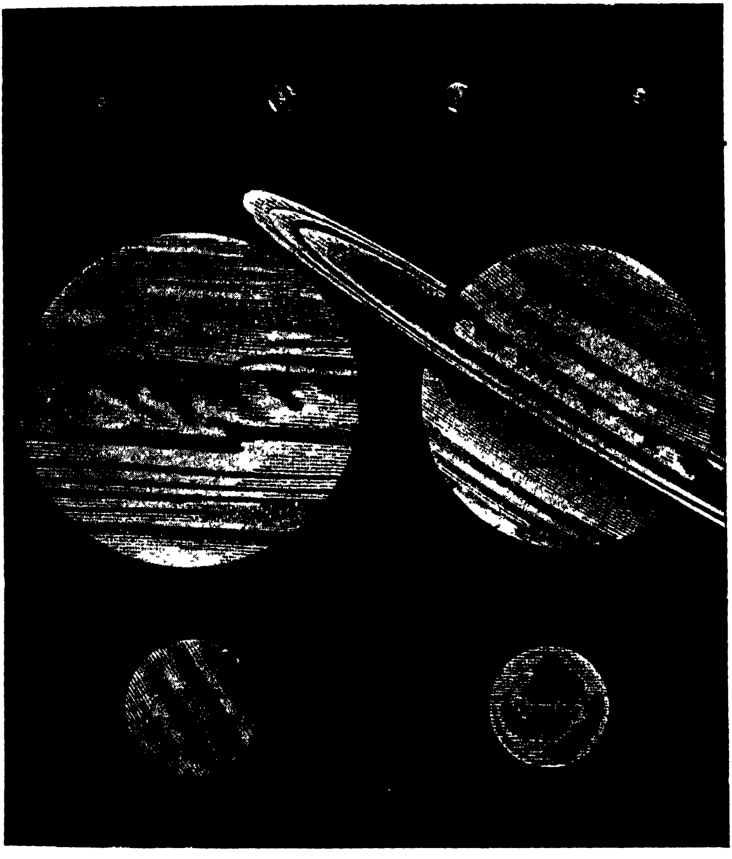


FIG. 21.—The Comparative Sizes of the Planets. (After *Flammarion*.) Reading from left to right downwards, the planets are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune. The ninth and recently-discovered Pluto is not shown. It "appears to be hardly larger than Mercury" (*Jeans*), and may be imagined as a small circle to the right of Neptune.

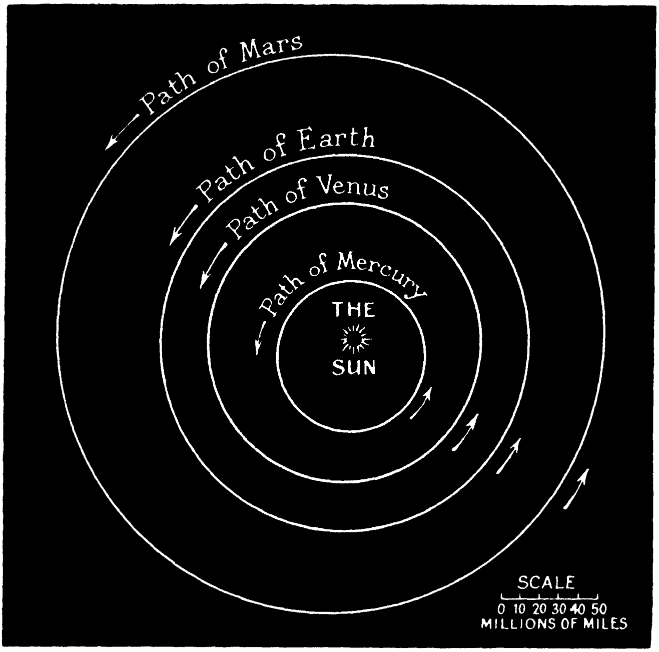


FIG. 22.—The Orbits of the Four Planets nearest the Sun.

newly-discovered Pluto. I have given them in the order of their distance from the sun, Mercury being the nearest and Pluto the farthest.

In early days most of the bright bodies in the heavens were supposed not to move, and they were called fixed stars, though, as a matter of fact, there are no fixed stars, for all the stars are suns, and they all move.

But the sun and moon and a few bright bodies were clearly seen to move, and the Greeks called these moving bodies planets, which means the wanderers. They enumerated seven, the sun, moon, Mercury, Venus, Mars, Jupiter, Saturn; and this is why we have seven days in the week. These days, some of which still retain their planetary names, as Sun's day, Moon's day, Saturn's day, were treated with great reverence and included in various religious systems. Now, however, we do not regard the sun and moon as planets, but Uranus, Neptune, and Pluto have been discovered. These, with the others above-mentioned and our earth, make up the nine planets.

Note the smallness of the earth (Fig. 21) when compared with the larger planets, which we shall describe more fully. Their distances from the sun have been carefully calculated; but, as mere figures convey so little in the gigantic measurements of astronomy, we must show the facts by other means. The path in which a planet moves round the sun is called its "orbit," and Fig. 22 gives a correct idea of the distances. The bright, small body almost in the centre represents the sun. The smallest circle is the path of *Mercury*; the next the path of *Venus*; the third circle the path of the *Earth*; the greatest the path of *Mars*.

Between Mars and Jupiter is a wide gap, in which we should naturally look for another planet. In this gap, up to 1931, there had already been discovered 2,000 little bodies, called "asteroids," which probably represent a single planet that has burst into fragments. Most of these asteroids or planetoids are small, few of them being larger than, say, motor-buses. Two fresh ones were discovered early in 1931: *Ba* by Professor Lacchini, and *Ca* by Count Volta (great-great-grandson of the famous electrician who discovered the "voltaic" pile and thereby gave us the word "volt"). Both observers discovered the planetoids while working in the Pino Torinese Observatory. Five only of the planetoids have known diameters: *Ceres*, 477 miles, *Pallas*, 304, *Vesta*, 239, *Juno*, 120, and *Eros* with a mean diameter of only 18½ miles. In 1931 this planetoid was found to be sausage-shaped and turning about a short axis—hence the variability of its light; its long axis is 29, and its short 8, miles. While *Hector* is the outermost of the planetoids, and, therefore, the furthest from the sun and ourselves, with a year equal to 12·1 of our years, *Eros* is the innermost and consequently the nearest to us and to the sun. Its year is equal to 1·76 of ours, or 643 days. The last close opposition of *Eros* was in 1894. In 1931 it was again close to earth and was then very carefully observed by astronomers with a view to checking all the measurements of the solar system (and from them stellar measurements) in Earth–Eros terms.

The very small dot in the centre of Fig. 20 represents

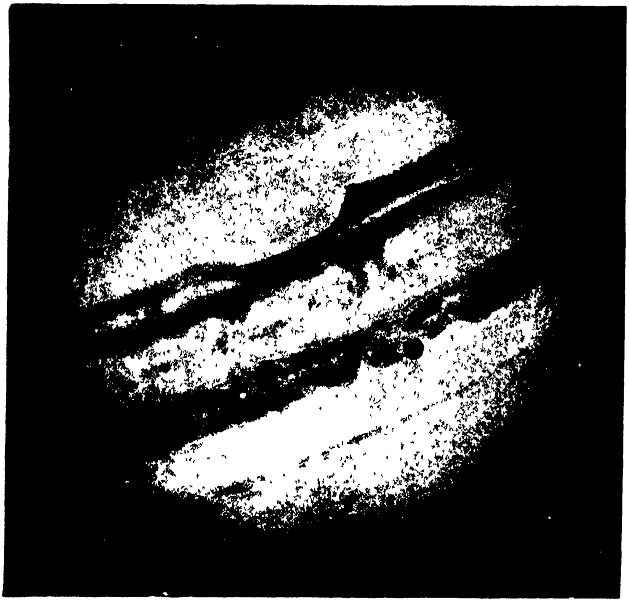


FIG. 23.—The Planet Jupiter. One of the nine moons is shown in transit.

the sun, a small circle marks the path of Mars; next is a ring of dots representing the asteroids; then comes a circle, the path of Jupiter; and beyond this the circles represent in order the paths of Saturn, Uranus, Neptune, and Pluto.

Nothing is more difficult than to realize these vast distances. As we have seen, the earth appears comparatively quite near the sun and yet it is nearly 93 million miles off. Various attempts have been made to bring this distance home to us. A bullet travelling at 2,500 ft. per second would require over six years to reach the sun, and a train running at sixty miles an hour would require 175 years to get there; yet light makes the journey in less than eight and a half minutes. Now, if you begin to grasp the distance of the earth from the sun, remember that the distance from Pluto to the sun is forty times greater!

The planets of our solar system are all, more or less, *dark* bodies, borrowing their light from the sun; they all rotate on their own axes; they revolve round the sun; and revolving around them are smaller bodies, called satellites, which also rotate on their own axes. Jupiter is the giant planet (Fig. 23). Its equatorial diameter is 88,500 miles, a little over eleven times that of the earth. In *volume* it is over a thousand times greater, but in *density* it is one-fourth that of our planet. Its surface is 122 times that of the earth, and its distance from the sun is 483 million miles. The huge planet is crossed by numerous lines—the famous belts—parallel to its equator. From its low density some think it probable it is a semi-sun, a hot liquid or gaseous ball producing its own heat by processes similar to those going on in the sun itself. It has a very extensive atmosphere of clouds and vapour whose reddish hue has been attributed to the transmission and reflection of light from the glowing red surface below.

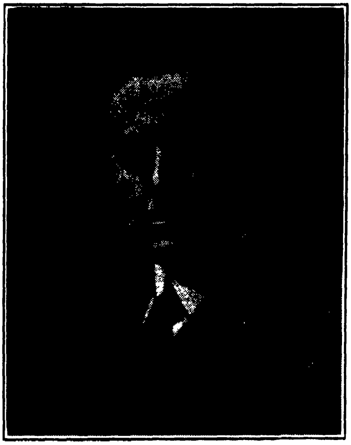
Many factors have to be considered in any estimate of the internal and surface temperatures of a planet. All the bodies of the solar system being offspring, so to speak, of a common parent, they may be assumed to have started on their individual careers with the same quantity of heat, mass for mass. Just as a big iron casting takes a week or so to cool, while a very small one takes but a few minutes, so the bulkier bodies of the solar system conserve their heat more effectively than the smaller ones. Again, some of the planets were born far away from the centre of the sun, some relatively close to it, others at intermediate situations between the two extremes. Mercury, close to the sun, is to all intents and purposes roasted; while Pluto, about the same size, shivers on the confines of the system, where the thermometer would stand at 480 degrees of frost. This distance-of-planet-from-sun factor has led Sir James Jeans to the opinion that the outer planets must be colder than anything we ever experience on earth and that " even Jupiter . . . must be about 270 degrees below zero on the Fahrenheit scale. . . . The clouds of Jupiter must presumably be clouds of carbon dioxide, or of some other gas which only condenses at very low temperatures." In any case it is obvious the planet is not fitted to be an abode for life. Finally, we must not omit to mention that this giant among the planets is attended by nine moons.

FIG. 24.—The Planet Saturn. (After *Flammarion.*)

Saturn (Fig. 24) is the show planet of our system. It is unique in that it not only has nine moons [1] but is surrounded by a series of " rings " such as has been found nowhere else in the universe. Its mean distance from the sun is 886 million miles and its greatest distance from the earth over 1,000 million miles. It is even further removed from solidification and adaptability for bearing life than is Jupiter. The most remarkable peculiarity of Saturn is the system of rings, first discovered by Galilei, though their true nature remained unknown for nearly fifty years till Huyghens, in 1655, explained them. But it was not for another twenty years that the apparently single ring was resolved into two with a dark zone separating them, and in 1850, both here and in America, a third ring was discovered. These rings, the brightest of which is about 17,000 miles broad, are not continuous sheets of incandescent matter, but swarms of moonlets each circulating around the mother planet in approximately the same plane. " There is every reason for thinking," says Sir James Jeans, " that these tiny moons are the fragments of a body which at one time formed a quite ordinary full-sized moon of Saturn. This probably entered the danger-zone of Saturn . . . and paid the usual penalty of being shattered into fragments." Just as in the remote past a passing star tore out a part of our sun and thus formed the planets; just as the sun tore out portions of Jupiter and Saturn and formed their moons; so "Saturn itself broke up its nearest satellite into millions of fragments and so formed its own system of rings." For every smaller body of a plastic nature revolving around a larger one there is a danger zone, to enter which spells disaster for the smaller body. Saturn's innermost satellite is only just outside this danger zone. Shortly, possibly before the extinction of life on earth, its orbit will have contracted sufficiently for it to enter the zone; then it will burst and its fragments form yet another ring. A similar, though not quite so imminent, fate awaits Jupiter's innermost satellite. "In the same way," says Jeans, "although in the very far future, our own moon must inevitably be drawn in closer and closer to the earth, until finally it approaches too near for safety and meets the same fate. After this the earth will have no moon, but will be surrounded by a frill of rings like Saturn." Thus does the sword of Damocles hang over the innermost satellite of a planet.

---

[1] The existence of the tenth satellite, thought to have been discovered by Pickering in 1900 and named *Themis,* is still *sub judice.*



Russell, London.

FIG. 25.—Sir James Jeans.

We must now call attention to the most extraordinary behaviour of the outermost satellites of certain planets. The only known moon of Neptune, the outermost one of Saturn, and the two furthest ones of Jupiter, do not revolve, like normal satellites, round and round the equator of the parent planet, but in a plane more or less at right angles to the equatorial plane, that is, they revolve in a meridional plane passing through the planet's two polar regions. The most plausible explanation of this exceedingly irregular conduct is that these particular satellites were not born of the planet to which they are attached. They are really foster children that have been annexed. It is supposed that the powerful pull of these massive planets detached certain of the larger asteroids from their orbits and compelled them thereafter to move in a new orbit about the planet.

Uranus, just visible to the naked eye, has a diameter of 31,000 miles and is 1,782 million miles from the sun. It has four moons.

We must refer to Neptune more in detail, because its discovery is one of the greatest triumphs of mathematical astronomy since the time of Newton. It was noticed that Uranus did not move in the orbit in which, according to all calculations, it ought to have moved. The mathematicians concluded, therefore, that there must be some other planet which drew it away from its proper path. So accurate were their calculations that they were able to tell the astronomers exactly where to search for another planet; and in that very spot Neptune was discovered on the night of September 23, 1846, by the Observatory at Berlin. Leverrier, a Frenchman, and Adams, an Englishman, both separately made this discovery by mathematics. The mean distance of Neptune from the sun is 2,800 million miles. It completes a revolution about the sun in 164·8 of our years; its diameter is 33,000 miles; and it has one moon.

Up to the beginning of 1930 Neptune was the outermost known planet of our solar system. About 1915 Dr. Percival Lowell predicted the presence of yet another body moving in an orbit outside that of Neptune. His prediction was verified in 1930 by Mr. C. Tombaugh of the Arizona Observatory. *Pluto*, as the new planet has been called, has a more elliptical orbit (eccentricity, 0·25) than any other planet, so much so that at perihelion (*i.e.* when nearest the sun) it actually cuts across the path of Neptune. The mean distance of Pluto beyond Neptune is 1,000 million miles, which would give it a distance of 3,800 million miles from the sun. The new planet has about $\frac{1}{1000}$th of the brightness of Neptune. Heavenly bodies are classified, according to their brightness as seen from earth, in divisions called "magnitudes," which, however, bear no reference to size. The brightest stars are called "first magnitude"; those just visible to the naked eye, "sixth magnitude" stars; and so on. On a photographic plate, after an hour's exposure, a "fifteenth magnitude" planet, such as Pluto, leaves a tiny streak—due to the planet's motion; whereas a star, being "fixed," leaves a round image. Thus the known diameter of our solar system has been increased, through the discovery of Pluto, to 7,600 million miles.

An illustration may help towards a conception of the dimensions of the space in which the members of our own solar family are poised. Let a globe two feet in diameter represent the sun. A mustard seed 132 feet away would then stand for the innermost planet, Mercury; a pea 142 feet distant would represent Venus, and another 215 feet away, our earth. A hemp seed at 327 feet would stand for Mars; several grains of sand sprinkled around the 550 point would represent the asteroids, while a tennis-ball a quarter of a mile off and a billiard-ball 700 yards away would stand respectively for Jupiter and Saturn. Finally, a cherry half a mile, a walnut a mile and a quarter, and a pea two miles distant from the two-foot globe would represent respectively the positions and sizes of the outermost planets, Uranus, Neptune, and Pluto. If, now, you were to put an orange 8,000 miles off, on the opposite side of the earth, it would represent the nearest star to our sun!

The moon is a dead and airless world, whose surface is covered with extinct volcanoes, as the wonderful photograph given here (Fig. 26) shows. It has had its birth, childhood, and maturity, suffered the decay of old age, and has finally died. In these respects it differs entirely from Jupiter and Neptune, which are still in their fiery, active youth. Strange thoughts arise when one contemplates the solar system as a family, in which some

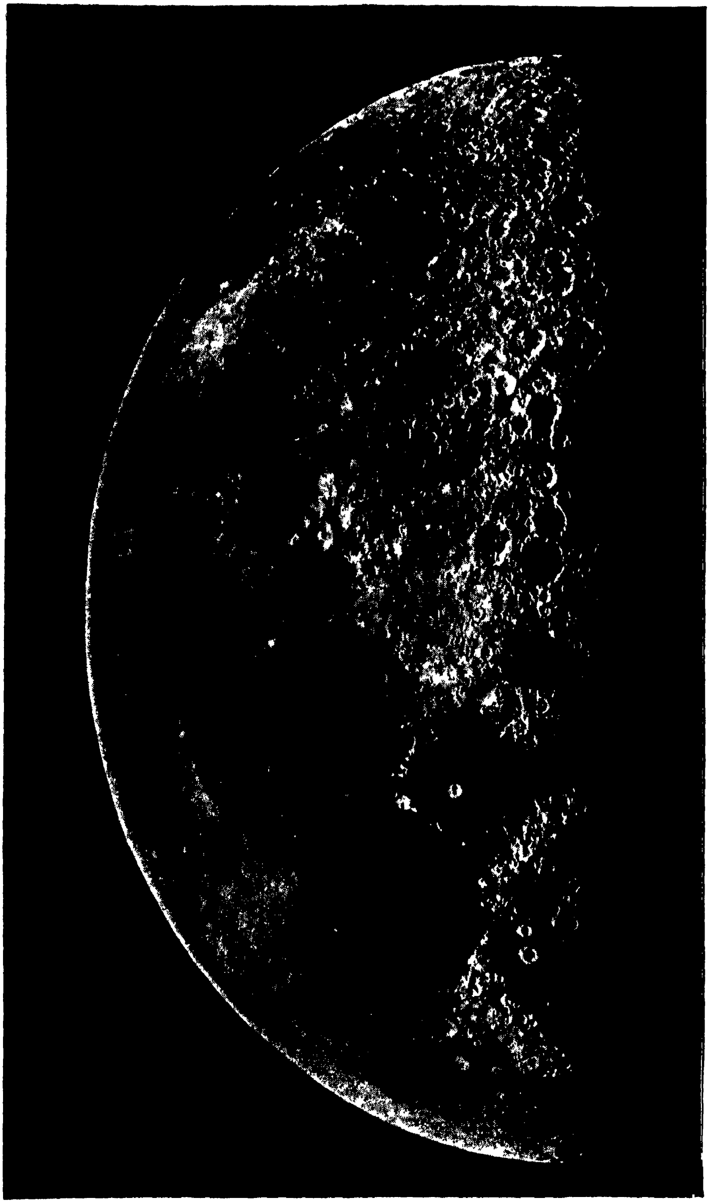


FIG. 26.—Moon at First Quarter.

are young, some in the prime of life, some aged and worn out.

Our solar system is an island surrounded by a stupendous engirdling void, in which the nearest known neighbour system is at a distance quite inexpressible by earthly numbers. In order to indicate how far away it is, we must express the distance in one or other of the units of measurement made use of in astronomy: (1) the earth–sun distance, 93 million miles; (2) the *Siriometer*, a million earth–sun distances; (3) the distance covered by a ray of light, travelling at 186,000 miles a second, in one year; this is the "light-year" or 6,000000,000000 miles; (4) the *Parsec*, 3¼ light-years, or about 20,000000,000000 miles. The nearest star to us, *Proxima Centauri*—a faint member of the *Alpha Centauri* group—is 4·1 light-years distant.

The number of stars which can be seen by the naked eye (including cases where a binary—two stars revolving round a common centre—is seen as one) is about ten thousand. But the camera-telescope "sees" and records stars so distant that no human eye, even though aided by the most powerful lenses, can see them. The number of *recorded* stars must be well over 300,000 million. Sir James Jeans thinks that the stars in *our* system alone "may well be of the order of 400,000 million." About two million extra-galactic (*i.e.* beyond the Milky Way) nebulæ are visible in the 100-inch telescope, and each of these holds, on the average, 300,000 stars, so that there are, in the words of Jeans, "thousands of millions of millions of stars within the range covered by the 100-inch telescope." Again, the number of dark bodies (obviously outside any numerical reckoning) may (Arrhenius thinks they certainly do) exceed the luminous ones. Beyond these extra-galactic systems, out and ever out in the depths of unplumbed space, the law of continuity indicates that "universe must follow universe in procession up to infinity." This latter view, no doubt, conflicts with that held by certain relativist astronomers who claim that the universe has a definite finite boundary, but their claim is based principally, not on direct observation, but on higher mathematics.

When we remember that the stars are suns, just as our sun is a star, and that probably each star has its own system of planets, though they are too small to be seen at such an immense distance, we begin to feel dazed by their infinite numbers and distances. We turn, therefore, with enthusiastic curiosity to inquire how this system of bewildering marvels has arisen; if it bears any marks of growth or of decay, of its origin or of its end. Were the heavenly bodies made once for all as they are now, or have they been evolved by the same laws which have produced the protozoa of the ocean and the geniuses of mankind?

Until the last few years the *nebular hypothesis* was generally accepted by astronomers as accounting for the gathering together into one orderly system of our sun, planets, and satellites. To-day, however, so far as our solar system is concerned, it has been abandoned in favour of the *tidal-disruption hypothesis*, although as explanatory of the origin of certain star systems the nebular hypothesis is still as firmly established as when it was formulated by Kant, Laplace, and William Herschel.

FIG. 27.—Laplace. Born 1749; died 1827.

Kant spent his life as professor at the University of Königsberg. In 1755 he first announced that all the bodies composing the solar system originated from a vast contracting nebula. Afterwards he abandoned scientific speculation and achieved immortality as a metaphysical philosopher. Laplace was the son of a farmer, but through the influence of D'Alembert he obtained the post of Professor of Mathematics in Paris. In 1796 he advanced the famous nebular theory, based entirely on mathematics. The hypothesis has become especially associated with his name, because he went into great detail and presented convincing mathematical evidence in its support. Herschel came to England from Hanover at the age of nineteen, and settled at Bath as organist and music teacher. His hobby was making telescopes and studying the heavens at night. On the 13th March, 1781, he discovered the planet Uranus, which at once made him famous. He gave up music, constructed better telescopes, and settled at Slough, where for forty years, aided by his illustrious sister Caroline, he was engaged in solving some of the mysteries of the universe. His constant labours soon revealed the fact that between those diffused wisps of luminous, cloud-like matter that characterize a nebula and an object hardly distinguishable from a star with a slight haze round it, *every intermediate grade* could be found. In this way he was led to the splendid theory of the gradual transformation of nebulæ into stars.

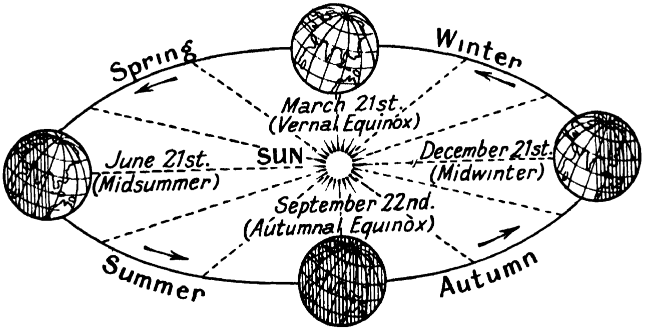


FIG. 28.—The Earth's Orbit or Path round the Sun.

Whatever views we of to-day may hold with regard to the nebular hypothesis, all must agree that it has a most marvellous history. Kant by abstract speculation, Laplace by mathematical calculation, Herschel by direct observation, independently came to the same conclusion—that the whole universe has evolved, and that the stars, suns, planets, and other bodies within it have attained their present form by condensation from an enormously attenuated and diffused gas. This is the great nebular hypothesis. Though *nebula* is the Latin for a mist or cloud we must not think of the nebula from which stars have come as like the mist or cloud of our atmosphere, but rather as composed of much lighter gases than any with which we are familiar. Hypothesis (Greek: *hypo*, under, and *tithenai*, to place) means a scientific " supposition " to explain observed facts. That stars, suns, and planets were formed from some primal mist is the explanation offered by the nebular hypothesis. As formulated by the three illustrious men we have named, their hypotheses naturally differed in points of detail, but in the main they all agreed. Kant first gave the theory to the world in 1755. Since then hundreds of men have devoted their lives to astronomy and thousands of discoveries have been made; and we have now to inquire whether, after all these years of remarkable scientific activity, the evolution of the millions of worlds is proved or discredited.

We will glance at the history of the earth and the sun. The earth's orbit is not a circle, but an ellipse (Fig. 28).

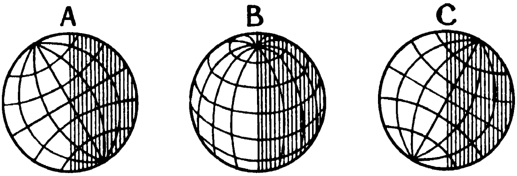


FIG. 29.—Different Inclination of the Earth to the Sun.

The different positions of the earth as it goes round the sun are the causes of the seasons of the year by reason of the change in inclination of the earth, as shown in Fig. 29. *A* is the position at the summer solstice (about June 21), *B* at the equinoxes (about March 21 and September 22), and *C* shows the position at the winter solstice (about December 21).

We must not suppose that the earth turns upon a *material* axis such as that represented by the needle in Fig. 30. It swings round the sun in space, but while doing so it has also a rotatory motion, that is, it turns round, as if upon an axis, once every twenty-four hours.

We ought to try to grasp the extraordinary motions of our little earth: (*a*) it rotates on its own axis so that a point on the equator is moving at the rate of 1,000 miles an hour; (*b*) in going round the sun once a year its centre has to travel more than 1,000 miles a minute; (*c*) by the sun's attraction it (as well as all the other solar bodies) is carried through space at a rate of over 40,000 miles an hour. Perhaps not one of these three principal motions is conceivable by us; and yet, in addition, there are at least eight other motions, so that we need not wonder that the earth never journeys twice through the same place.

The moon is the earth's satellite, and its birth formed one of the great epochs in the history of our earth. Though we cannot trace this history to that point when the earth left the sun, we can trace a good deal of the history of the casting off of the moon by the earth. Sir George Darwin, son of the illustrious Charles Darwin, has worked out the details of this parting company of the two bodies with amazing accuracy. At that time the earth must have been in a somewhat plastic if not fluid state and, moreover, rotating very much faster than it

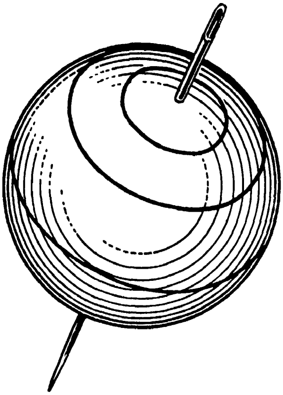


FIG. 30.—The Earth turning upon its Axis.

(After *Flammarion.*)

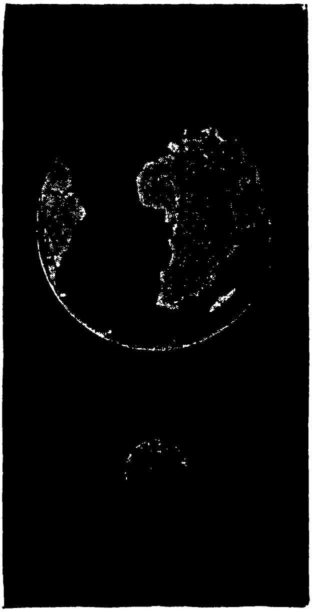


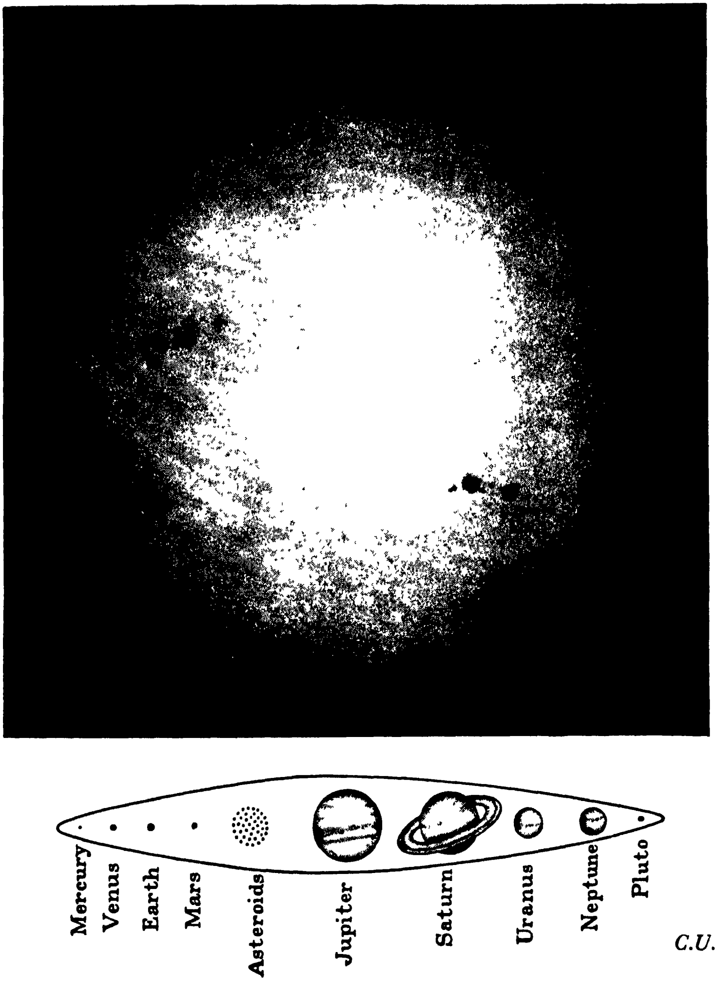
FIG. 31.—The Relative Sizes of the Earth and the Moon.

(After *Flammarion.*)

does at present, otherwise the centrifugal force due to its rotation would not have been able to throw off the moon. According to Sir George Darwin a great treacly mass became detached from the spinning earth, much as a drop of water flies off from one of the tassels of a spinning mop. Now, just as the moon causes tides on the earth to-day, so the earth caused tides on the moon. Sir George goes on to describe how immediately after the moon was thrown off, and while it was revolving very close to its parent, colossal tides were raised on each of the two semi-fluid bodies. A twofold reaction resulted from the tidal friction: the moon's orbit became twisted from a circular into an eccentric form, while both earth and satellite were forced further and further apart. Even at the present period of the earth–moon history, when our satellite is in perigee, that is, when she is nearest to us, the tidal effects are much greater than when she is in apogee.

Yet another effect of the tidal reactions consequent upon their mutual attraction is a disharmony between their periods of rotation and the period of revolution of each round the other. " Something like fifty-seven million years ago," says Professor Turner, " there was only one day in the month, that is, the moon was running round the earth as quickly as the latter rotated on its axis."

As applied to the formation of suns and their attendant planets, Laplace's theory is now considerably modified. In recent times we have discovered more than a hundred thousand nebulæ in the heavens, so that we have full confidence in regarding them as the stuff out of which worlds are made. The " nebular hypothesis " is therefore as strong as ever so far as the majority of star-systems is concerned. Where it breaks down, as already stated, is with reference to the general conformation—the relative masses, motions, and positions—of the several members of our own family of sun and planets, to account for which one or other of the two tidal-disruption theories is now held by scientists. These theories assume that some billions of years ago a star of greater mass than our sun came within close proximity, say a few million miles, of it. Even if such a star came within 5,000000 miles, it would exert a " tide-raising " force some 16,000 times greater, relative to surface gravity, than that of the moon on the earth. As the combined result of the " pull " of the star and the internal disruptive forces set up thereby in the interior of the sun, great masses of the latter were expelled excentrically. Chamberlin and Moulton think this occurred at two antipodal points on the sun's equator. The approach and retreat of the passing star imparted a



C.U.P.

FIG. 32.—The Sun and Planets drawn to scale.

tangential motion to the two arms of torn-out gaseous matter, thus causing them to revolve around the central mass of the sun, and prevented their falling back into it after the star had passed on. These two gaseous arms, eventually condensing at various points, became the planets and satellites, etc. Such is the *two-armed tidal-disruption* or *planetesimal theory.*

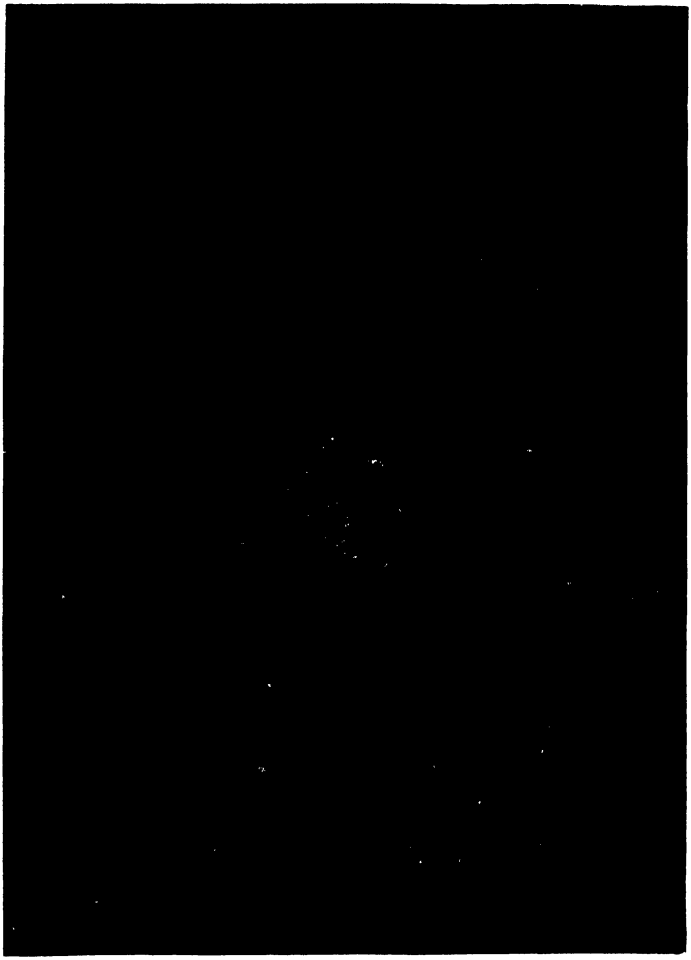


Fig. 33.—A Spiral Nebula.

Sir James Jeans, on the other hand, assumes that, since the tidal upheaval must have been principally manifested on that face of the sun nearest the passing star, there resulted from the mutual " pull " one long cigar-shaped filament of gaseous matter. This, he tells us, provided a fit playground for the processes of " gravitational instability." So condensations occurred in the " cigar," the larger ones in the neighbourhood of the central bulge, the smaller about the two pointed ends, and these ultimately became the planets; the larger ones being accommodated in the bulge of the cigar, the smaller ones towards the narrower regions. Such is the *one-armed tidal-disruption theory* of Jeans (see Fig. 32).

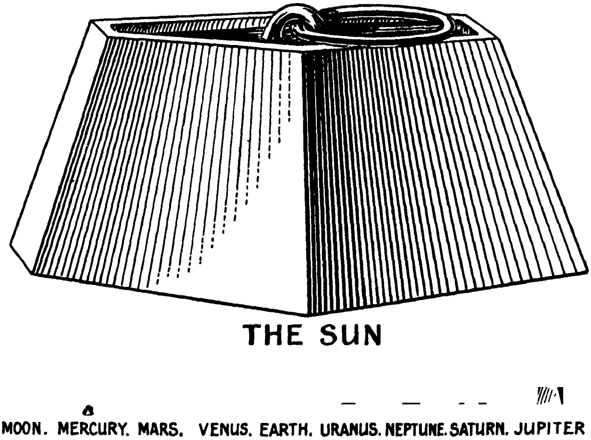


Fig. 34.—Weights representing the Masses of the Celestial Bodies. (After *Flammarion.*)

If you examine closely the accompanying photograph, Fig. 33, you see that the nebula has not a series of rings, but two great fiery spiral arms winding round it. This is the general shape of nebulæ, a shape that indicates the real way worlds are made. You can see the fiery material of the arms actually gathering at certain points, as if to form planets, while the central mass is turning into an immense sun or group of suns. It is a living picture of worlds in the making.

Let us now turn to the history of the sun. In addition to the sun, the solar system consists of nine planets, thousands of planetoids or asteroids, meteoric bodies, comets, cosmic dust, molecules, atoms, proto-atoms, radiations, and electro-magnetic waves.

So huge is the sun as compared with the subordinate members of his family that if all the planets and satellites could be piled into one mass, they would weigh but a small fraction $\left(\frac{1}{740}\right)$ of the weight of the sun (Fig. 34). We must remember that all the matter now forming the solar system once existed as a huge nebulous mass, $\frac{1}{200,000,000}$ of the density of our lightest gas, hydrogen, extending far beyond the orbit of Pluto.

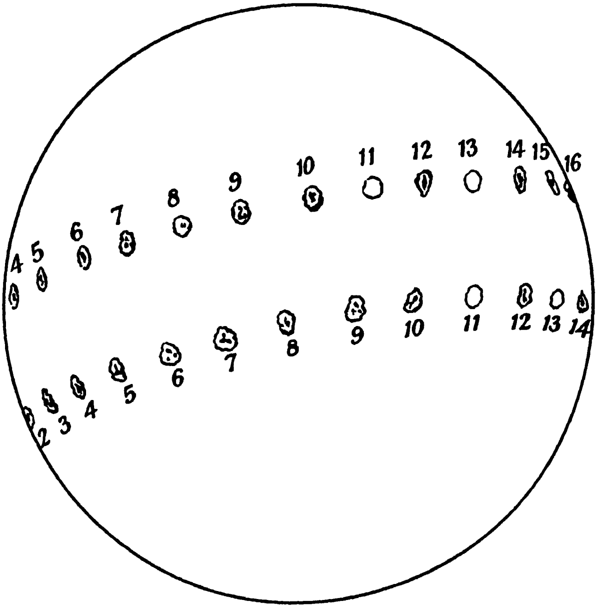
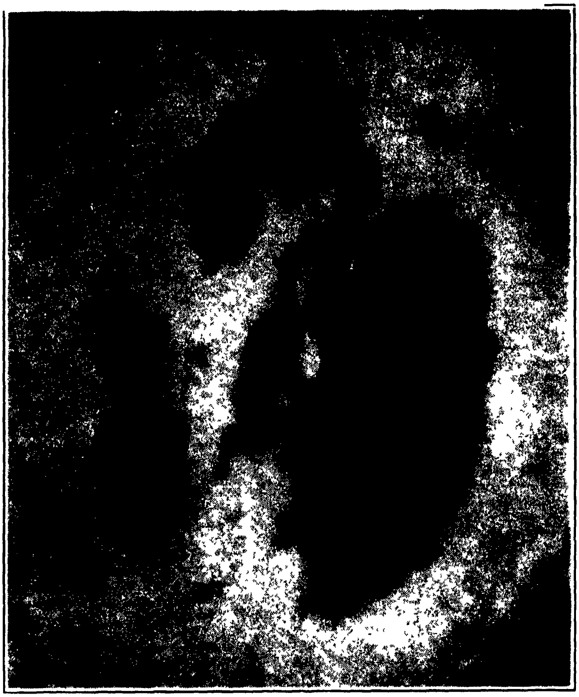


FIG. 35.—Two Sun-spots. (After *Flammarion*.)

In Fig. 32, we see some sun-spots, but little idea is conveyed of their vast size. In Fig. 35 are *two* spots, one above and one below the equator, that have been drawn sixteen times as they were being carried round by the rotation of the sun. In fact, they afford us the means

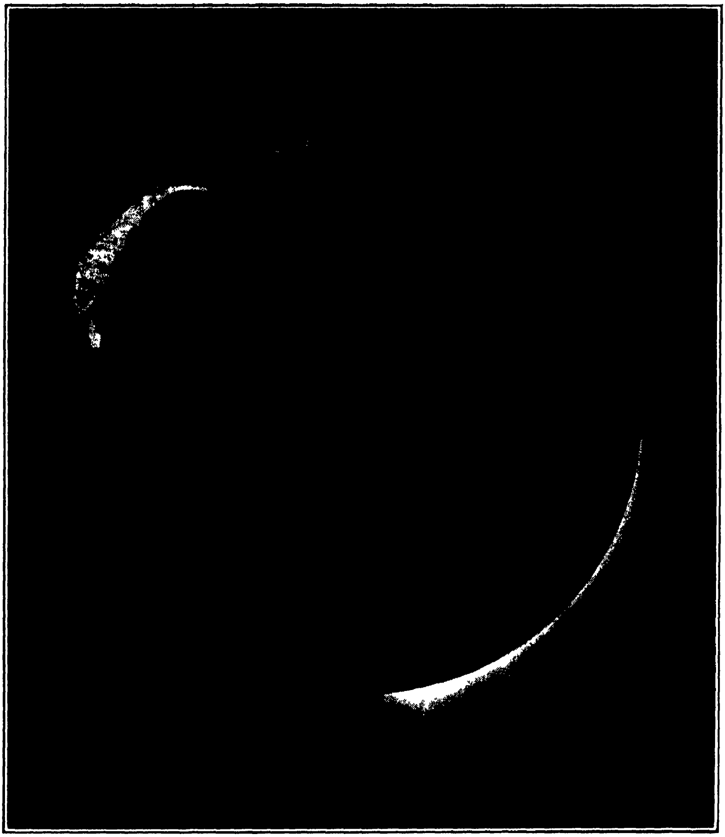


Royal Observatory, Greenwich.

FIG. 36.—A Sun-spot.

of measuring the time which the surface of the sun takes to rotate. Fig. 36 is a photograph of one of the largest sun-spots. What these spots are, how they are caused, and whether they affect the weather on our planet or not is still undetermined, but they are undoubtedly magnetic, for two adjacent sun-spots behave like the opposite poles of a horse-shoe magnet; in fact, every "sun-spot" is linked up with some other spot having an opposite kind of magnetism. The eleven-year magnetic storm cycles, that synchronize with an exacerbation of sun-spot activity, are almost certainly causally related to the corresponding periodicity of our terrestrial magnetic disturbances.

When there is an eclipse of the sun, remarkable flame prominences are seen on its surface, as shown in Fig. 37.



A. C. Crommelin, Greenwich Observatory.

FIG. 37.—The " Ant-eater Prominence."

With their perfected instruments modern astronomers can observe these flames at any time, without having to wait for an eclipse. They can even photograph the great storms in the sun's dense atmosphere. These flames are over 124,000 miles high.

This brings us to the very interesting question of the source of the heat of the sun. Heat is only a form of energy, and energy, like matter, cannot be created out of nothing. We have, therefore, to inquire whence comes the energy which supplies the heat of the sun. To grasp, even partly, what is implied by the amount of heat radiated by the sun we must gain some notion of the sun's size. Its diameter is 865,000 miles—*i.e.* one hundred and eight of our earths could be threaded, like beads, along it. Its surface area is 12,000 times, while its volume or bulk is 1,300000 times, that of the earth. In fact, were the sun hollow, there could be placed inside it the earth together with the moon circling round her, yet not half of the sun's interior would be occupied (Fig. 38).

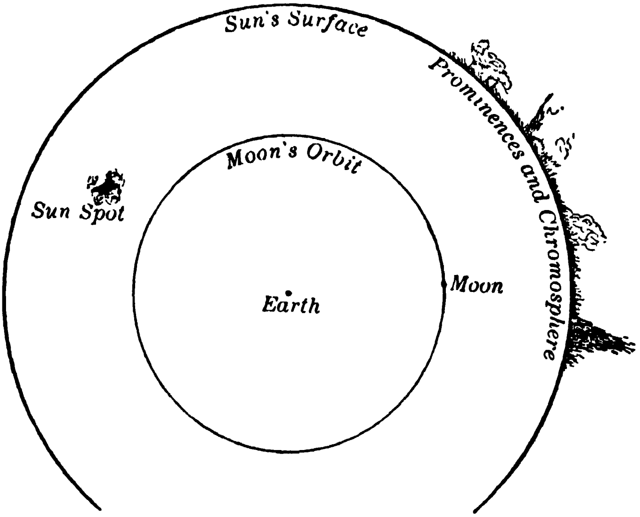


FIG. 38.—Dimensions of the Sun compared with the Moon's Orbit. (After *Young*.)

Note, again, how small are the earth and moon as compared with the sun-spot and the flame prominences.

Now, with this representation of the size of the sun, let us try to form some idea of its heat. The sun is not a fire deriving its heat from the combustion of some material, as does an ordinary fire when coal and wood are burnt up. It would require the burning of thousands of billions of tons of coal every second to produce the present heat and light of the sun, the light alone being 3,230,000000,000000,000000,000000 candle-power.

If the sun were a solid mass of coal, and there were enough oxygen to burn it, it would only keep up its present rate of radiation for 2,800 years. But the sun has been giving out its enormous heat for over seven and a half million million years, and can continue to do this for millions of millions of years to come. So it is evident that combustion is not the source of its heat.

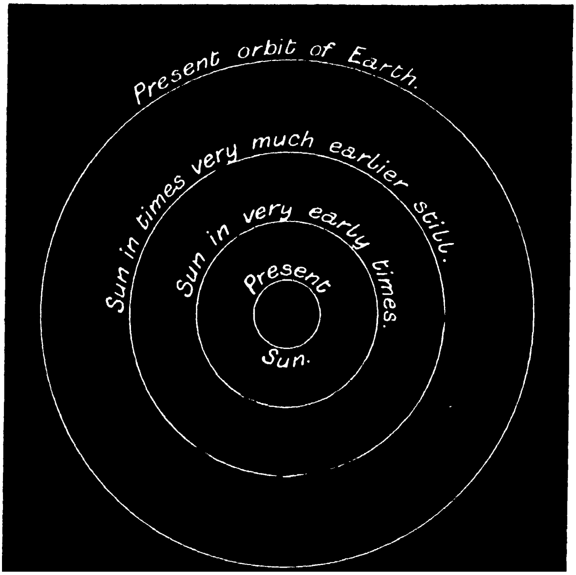


FIG. 39.—An ideal representation of the shrinking Sun. (After *Sir Robert Ball.*)

If the sun has contracted to its present volumc from a vastly larger volume of gaseous matter that, in all probability, more than filled up a sphere with a periphery represented by the orbit of Pluto, such contraction must have caused an enormous rise of temperature through conversion into the kinetic energy of heat of the potential energy of the widely diffused myriad particles, as they gradually settled towards a common centre of gravity. We know that the sun is shrinking so rapidly that its diameter is a mile shorter every eleven years (Fig. 39).

Since the wise Hammurabi sat on the throne of Babylon 2,220 years B.C., the diameter of the sun has diminished some 375 miles, while in a million years the shrinkage has amounted to approximately 100,000 miles. Helmholtz considered that contraction of the sun accounted for the whole of its temperature, but Kelvin showed that the shrinkage that has already taken place could only maintain the sun's heat for about 50 million years, whereas geology alone tells us the sun must have been giving out light and heat for a vastly longer period than this. Since contraction is but a minor source of the sun's heat, we must search for other causes. The impact of meteors ever raining down on the sun's surface is also inadequate. Jeans has recently pointed out that even the fall of our earth into the sun would only maintain its extravagant rate of radiation for 100 years. If the sun's maintenance of heat were dependent upon the infall of matter, this would have to be of such a quantity that the sun's weight would be doubled in 30 million years, whereas we now know that our luminary is actually *losing weight at the appalling rate of* 360,000 million *tons a day, or* 4 million *tons each second.* The sun that sees this book through the press is lighter by some 10,000 million million tons than the sun that shone on the Indian Mutiny in 1857 ! Despite such loss there is no visible shrinkage of our orb with the passing of the centuries. This is due, of course, to its prodigious mass of 2,000,000000,000000,000000,000000 tons. The radiation of energy from, and consequent loss of weight of, the sun was, says Jeans, still more furious in the past, though in the future it will get less and less—just as the sand in an hour-glass runs out fastest at the start and slowest towards the end. Other suns than ours, more massive and hotter, are losing weight even more rapidly. According to Jeans, *S. Doradus*, in the Magellanic cloud, is emitting radiation so lavishly that it is losing weight 300,000 times faster than is our sun. A good idea of the rate at which the latter is wasting his substance in riotous radiation may be gathered by looking at the Thames as it rushes seaward under London Bridge and reflecting that there would have to be 10,000 such rivers flowing past to equal the present pouring away of matter into space by the sun.

Sir G. H. Darwin says: " It does not seem unreasonable to suppose that 500 million to 1,000 million years may have elapsed since the birth of the moon " from the earth. This demands that the age of the sun must be vastly longer than physicists have hitherto allowed. For forty years there has been this difficulty between the demands of geologists and the conclusions of the physicists. But recent discoveries in radium show that contraction of the sun and falling meteors are not the only sources of the sun's heat. Radium is, perhaps, a million times more powerful than dynamite. Twenty-two ounces of radium would furnish enough energy to tow a ship of 12,000 tons a distance of 6,000 sea miles. Now we know there are radio-active forces in the earth and it is practically certain that the sun is intensely radio-active. If there were as much radium in the sun as would be equal to one three-hundred-thousandth part of its mass, it would keep the sun's heat going for 1,000 million years. Nevertheless, contraction, fall of meteors, and radio-activity do not suffice, even in combination, to keep up the sun's extravagant emission of energy.

Modern physics is only able to suggest one process capable of providing a sufficiently long life for a luminous —that is, radiating—star; it is the actual annihilation (so called) of matter. Obviously a heavy star can only change into a lighter one if material is removed; and this is effected, says Jeans, through annihilation of the atoms and their transformation into radiations. *The radiations possess weight*, but once they have left the luminous body and become extra-stellar, their weight no longer affects the star. By annihilation—a particularly misleading term to be selected by physicists—is meant, not the conversion of something—matter, electrons, protons, radiation—into nothing (a process as inconceivable as the creation of something out of nothing), but the disappearance of something *as such* and its reappearance under another form. This book, if burnt up, is annihilated as a book, but its " mass " remains as smoke, vapour, and ash, together with heat, light, and other radiations; and these components might conceivably, in the future, be resynthesized into another edition of the work. " The two fundamental corner-stones of nineteenth-century physics," says Jeans, " the conservation of matter and the conservation of energy . . . are replaced by the conservation of a single entity which may be matter and energy in turn. Matter and energy cease to be indestructible and become interchangeable. . . . Heat, light, electricity, have all in turn proved to be forms of energy; the annihilation hypothesis only proposes to add another to the list, so that matter itself also becomes a form of energy."

At the birth of the sun, about seven and a half million million years ago, energy became stored up in the protons and electrons of which its atoms were constituted, and ever since that time the sun has been pouring out energy and losing mass, and will continue to do so for millions of millions of years more. This energy, says Jeans, is being emitted at the sun's *surface* at a rate of 50 horse-power per square inch. Yet only one atom in every 15,000000,000000 is broken up *per year* to produce this terrific stream of energy. How is this explained? The energy radiated away at the surface really comes from the whole depth of the sun down to its centre. The 50 horse-power manifested at each square inch of sun-surface has been produced inside a cone of sun material 433,000 miles long, whose apex is the centre of the sun, and base a circle with an area of a square inch on his surface. In such a cone Jeans has computed the number of atoms to be 1,000,000000,000000,000000,000000,000000, and out of this vast number 2,000000,000000 break up every second. The overwhelming proportion of the sun's heat is caused by this disruption of atoms within its interior, and our enjoyment of its heat is consequent upon the very minute fraction, $\frac{1}{2{,}200{,}000{,}000}$ of the whole, which our earth intercepts. The energy set free by atomic disintegration is 18,000 million times greater than that liberated during ordinary combustion. A pound of coal burned in our grate might warm us for a few minutes and perhaps, in addition, boil a couple of eggs, but the same pound atomically disintegrated would, says Jeans, "keep the whole British nation going for a fortnight, domestic fires, factories, trains, power-stations, ships and all; a piece of coal smaller than a pea would take the *Mauretania* across the Atlantic and back."

Eddington and Emden have calculated the central temperature of the sun to be 31,500000° C. Jeans, by independent measurements, arrives at the figure 55,000000° C. We need not concern ourselves as to which of the two figures is the more correct; sufficient for us is Sir James Jeans' assurance that if a bit of the sun's core the size of a pin's head could be brought to our earth, it would instantly consume every living creature within a radius of 1,000 miles.

One consequence of the sun's decrease in mass is that the earth and the other planets are receding from it in an ever-widening spiral. The earth's recession is small, only ⅜ inch per year. Nevertheless, on the geological time-scale such an amount is not negligible, for in a million million years the earth will be 5,700000 miles further from the sun; and this, coupled with the sun's diminished heat-producing power, will lower our surface temperature about 30° C., and man, if still surviving, will be experiencing another glacial period.

Before we turn to consider the great universe of stars, of which our solar system is a mere speck, we ought to say a few words about comets and meteors.

FIG. 40.—A Comet.

The origin of comets is not yet absolutely settled, but the general conclusion among astronomers is that they do not come from outer space but belong to the sun's family; they are, in fact, his aberrant offspring. The few cases where they pass the sun in apparently unclosed curves, such as the parabola and hyperbola, are probably due to disturbances produced by planets. Comets are composed of gases and of myriads of solid particles varying in size from specks of dust to push-balls. They react in a striking manner on the one hand to the sun's gravitational attraction and on the other to his radiation repulsions. Hence, while the head of the comet, containing the heavier particles, is pulled in a curve round the sun, the tail, containing the lighter particles, is "pushed away," so to speak, to that side of the comet's head furthest from the sun. The solid particles of the comet reflect the sun's light, but the gases are self-luminous and glow like those in an electrified vacuum-tube and probably for the same reason. Though the total mass of all the known comets is possibly less than that of the moon, yet a single comet spans enormous distances of space, sometimes over 100 million miles.

Meteors, or "shooting-stars" as they are popularly but erroneously called, are solid bodies principally composed of iron, and varying in size from dust to masses of hundreds of tons. They are relics of the primeval fire-mist originating our solar system, the leavings and parings left over after the other worlds had taken form or possibly the flotsam and jetsam of one of these wrecked in the making. Thousands of millions are caught annually by our earth, and of these only about one per cent. is visible. Those that enter our atmosphere at very high velocities are quickly raised by friction to incandescence, and many of them are completely volatilized. The weight of the earth is increasing at the rate of 100,000 tons a year in consequence of this meteoric rain, and as for the sun, 2,000 tons are falling into it every second!

When the relative velocity of a large meteor is sufficiently low to enable it to resist the action of our atmosphere, it completes its fall to the earth, and is then called an aerolite or meteorite.

Fig. 41 shows the celebrated meteorite which fell at Gross Divina, Hungary, in 1837, and weighs about twenty-four pounds. But this is puny in size compared to the meteorite which fell in Siberia in 1908 and which Sir James Jeans tells us "set up blasts of air which devastated the forests over an enormous area, while the shock of its impact on the solid earth caused waves which were recorded thousands of miles away." A huge three-mile circumference crater in Arizona is believed by scientists to have been caused by the fall of a yet larger meteorite. The finest collection of these bodies in the world is at Vienna, but the London, Paris, and Yale museums all have good collections. Our interest lies in the message which these visitors from far-distant regions bring to us, for they tell that all nature is one. Twenty-seven of the chemical elements, including argon and helium, have been found in them, but not a single *new element*. Many of their *minerals*, however, are not found on the earth, but for the most part they bear resemblance to terrestrial ones of volcanic origin. In short, meteors present us with no new elements, only with new combinations.

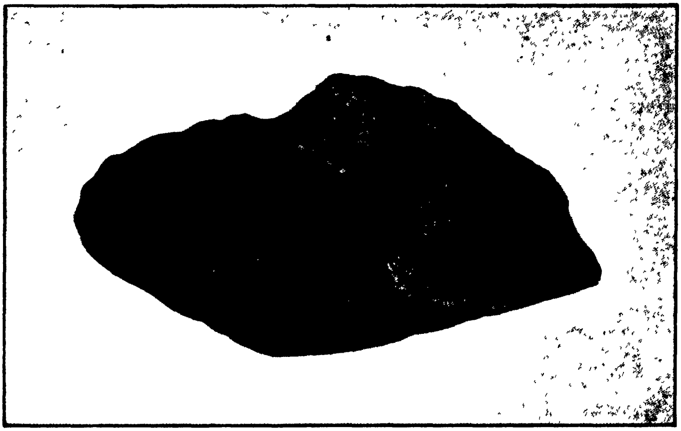


FIG. 41.—A Meteorite.

When we turn to the stars, words fail to convey any idea of their grandeur. We are dazed by their myriad numbers, colossal sizes, and vast distances. Among some of the finest spectacles in the heavens are the Globular Clusters, of which about a hundred are known. Each of these contains hundreds, even thousands, of stars, among which are those very mysterious types, the *Cepheid Variables*, whose alternating luminosities have enabled Professor Shapley to determine the distances of the clusters. And terribly remote they are, on the very

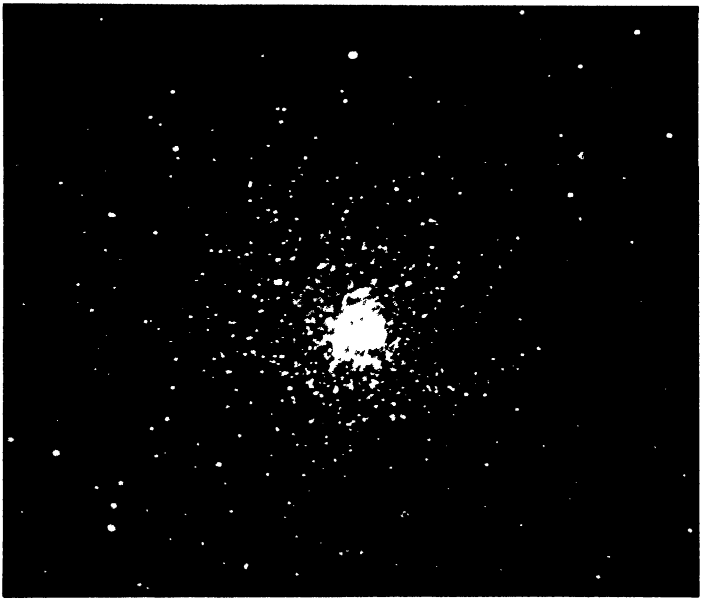


FIG. 42.—The Cluster in Hercules (*M.* 13). (After *Flammarion.*)

confines of the known universe, the nearest, *Omega Centauri*, being 22,000 light-years away, while the furthest, *N.G.C.* 7006, is 220,000 light-years distant. These star-clusters all look much alike, and *M.* 13 in Hercules shown in Fig. 42 may well stand for any of them. Of the total number of 10,000 stars visible without a telescope, about 3,000 can be picked out with the naked eye from any one position on a clear moonless night. Nine millions are brought into view by a moderate telescope and fifteen hundred millions by the 100-inch one. But the marvellously delicate apparatus of science bring a yet greater multitude of stars within the ken of man. We are told that in our own galactic system alone there are 400,000 million suns. Sir Arthur Eddington, using the apparent speed of recession of the nebulæ out beyond our Milky Way as a basis for his calculations, estimates the number of stars in the universe as reaching the figure 11,000,000000,000000,000000. Sir James Jeans' estimate is even higher—2,000000,000000,000000,000000.

The latter of these two brilliant British astronomers gives us a vivid illustration of this grand host of luminous orbs and a very profound impression of man's relationship to them. Suppose the stars to be represented by grains of sand scattered over an area equal to that of England, they would form a layer hundreds of yards deep. When we reflect that on this scale our own earth would be represented by one-millionth part of one of these grains, then, adds Sir James, " our mundane affairs, our troubles and our achievements begin to appear in their correct proportion to the universe as a whole." Be it remembered there are scientists who refuse to admit that the evidence for the relativist hypothesis of a finite dying universe poised amid a nigritudinous nothingness warrants the jettisoning of the Spencerian view of an infinitely extended and enduring universe. To them Sir James Jeans'

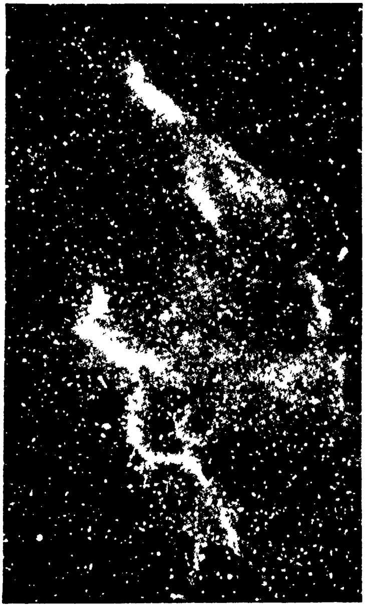


FIG. 43.—A diffused Nebulosity.
(*N.G.C.* 1499; in Perseus.)

2×10^{24} stars (and he only takes the luminous ones into his reckoning) will be less than a drop in the ocean.

With a three-sided column of glass such as one of those forming a chandelier you can split up " white " sunlight into its seven component colours—violet, indigo, blue, green, yellow, orange, and red. The seven-banded strip of colours produced by the glass prism, as well as that arch of colours called the rainbow produced by the raindrops, is called a spectrum. Various incandescent bodies and gases give various spectra, and by means of the spectroscope—which is but a telescope connected up with a series of prisms—chemical elements can be identified. This instrument has done even more for astronomy than the telescope, and among its great achievements is its power to distinguish between star-clusters and nebulæ. Nebulæ are of three kinds: (1) *Planetary nebulæ*, of which only a few hundreds are known, are probably stars sur-

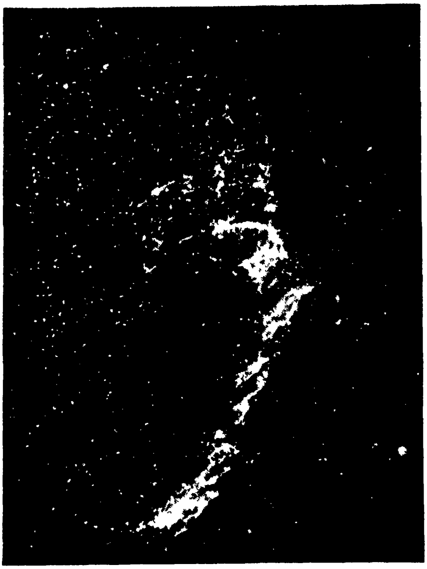


FIG. 44.—An irregular Nebula.
(*N.G.C.* 6992; in Cygnus.)
(After *Dr. W. E. Wilson.*)

rounded by vast luminous atmospheres and lying inside our Milky Way or Galactic Circle. (2) *Galactic nebulæ* also lie inside the Milky Way; they consist of vast clouds of green-coloured, glowing gases that often envelop a whole constellation of stars. Besides hydrogen and helium and the non-terrestrial gas, nebulium, they contain matter in the pre-atomic state. (3) The colossal *extra-galactic nebulæ*—so called because they lie outside our Milky Way—are usually white in colour and spiral in form. They are similar in general shape, as well as in the number of stars they contain, to our own muffin-shaped universe bounded by the Galactic Circle. Some two million of these nebulæ are visible in the 100-inch telescope, each containing enough matter to make 2,000 million stars. According to Jeans, the size of these nebulæ is of the order of "hundreds of thousands of millions of millions of miles." While some of the matter within them consists of relatively dense stars, yet other matter has a density one-millionth of that which we can obtain in our vacuum tubes. Fig. 45 shows the great chaotic nebula in Orion, one of the largest bodies in the heavens.

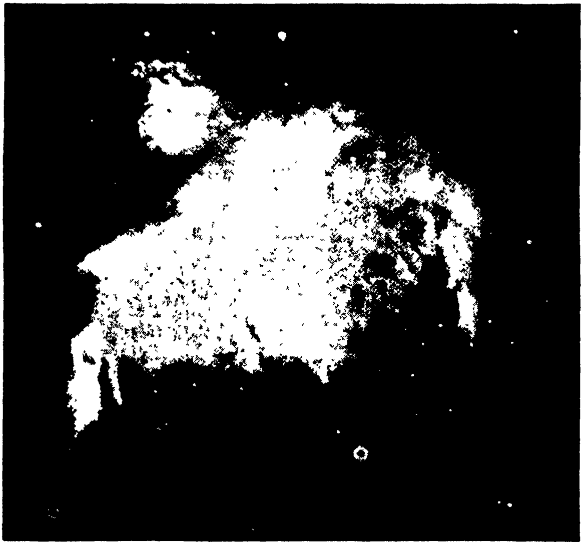


FIG. 45.—The great Nebula in Orion. (Lick Observatory.)

The spiral nebula depicted in Fig. 33 gives us some idea of the way in which heavenly bodies began to rotate and revolve.

Fig. 46 shows a " ring nebula "; it is probably a spiral seen edgeways. Fig. 47 is the nebula in Andromeda. This stupendous object, one of the most conspicuous of the extra-galactic nebulæ that are scattered through space at average distances apart of 63,000000,000000 miles, is just visible to the naked eye. We see it, not as it is now, but as it was 900,000 years ago! It makes a complete revolution in 19 million years. On first thoughts this might seem slow progress, but to accomplish it the outlying parts of the nebula have to hustle along at a speed of 100 miles a second! This body has a mass equal to 3,500 million, and a luminosity equal to 660 million of our suns (Jeans).

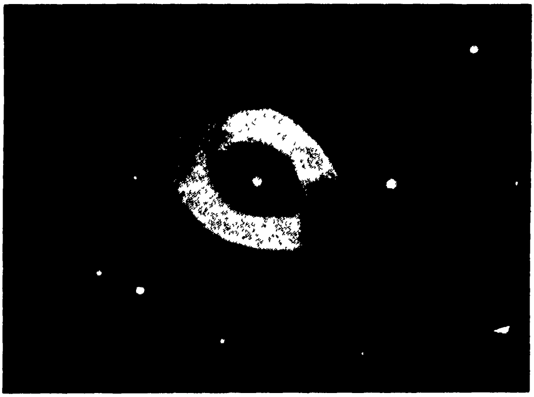


FIG. 46.—The Ring Nebula in Lyra. (Lick Observatory.)

Could anything more marvellous be discovered by man than that, in a body of such dimensions, the same law of Evolution prevails as in the speck of living jelly that gives rise to himself?

Modern science views the universe as made up of: (1) some 90 serially-related elements,[1] from hydrogen and helium at the light end, to radium and uranium at the heavy end of the series; (2) proto-atoms, that is, atoms not containing their full (terrestrial) complement of constituents, *e.g.* the iron we know on earth exists in the sun's atmosphere in various proto-iron states; (3) Electrons; (4) Protons[1]; and (5) Radiations. These

---

[1] Professor Papish, of Cornell University, has just discovered a new element, atomic number 87 (87 planetary electrons around proton nucleus), which occupies a position in the periodic table between Niton (86) and Radium (88).

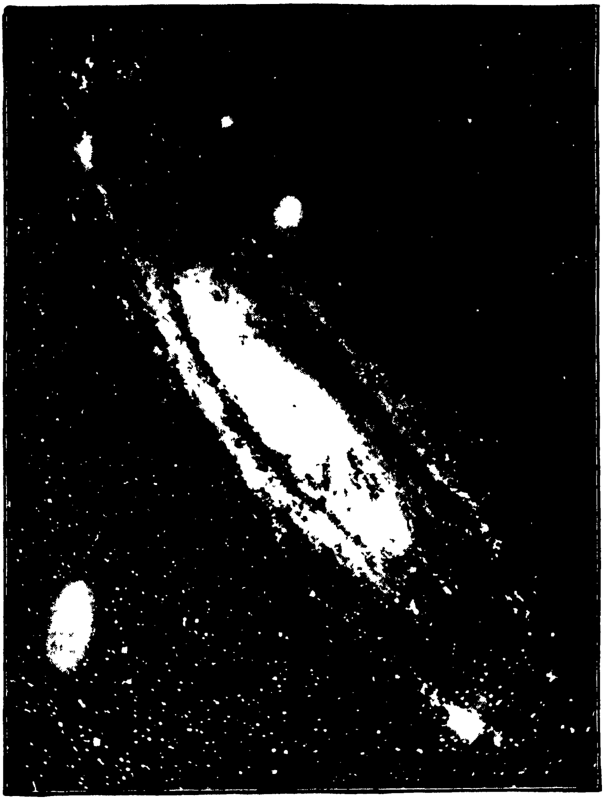


FIG. 47.—The Nebula in Andromeda.
(After a photograph taken at the Yerkes Observatory by *Prof. Ritchey.*)

---

[1] There is a distinct possibility that Dr. J. Chadwick, F.R.S., has discovered a third set of particles within the atom. The great authority, Lord Rutherford, F.R.S., stated on Feb. 27, 1932, that Dr. Chadwick's experiments "seemed to point to the existence of a ray whose particles, known as 'neutrons,' were indifferent to the strongest electric and magnetic forces."

entities are assumed to be, directly or indirectly, convertible, and each of them possesses mass and weight. Modern thermo-dynamics has led to two conflicting views of the future of the universe. Sir James Jeans believes it is doomed to a final heat-death; like a clock-weight, its energy is running down, so that at last the universe must come to a standstill when its energy is at a dead level and no longer available. Other cosmologists, however, take an opposite view, and one far more consistent with the principle of continuity which appears to underlie all Nature's processes. They believe that in her great laboratories matter is not only disappearing and reappearing as radiations, but that the latter are in corresponding degree disappearing and reappearing as matter. While the former processes may be taking place, as Jeans claims, in the central furnaces of the blue-white stars, the latter processes, Millikan thinks, are taking place in the intensely cold depths of extra-galactic space. On such a view the universe becomes a cyclic whole, without beginning or end, the triple fundamentals—protons, electrons, and radiations—of its total matter-energy content being a constant in perpetual flux. The cosmos has its tombs, but it likewise has its cradles!

CHAPTER THREE: GEOLOGY

ASTRONOMY has given us an outline of the manner in which the sun, moon, and stars have evolved from a form of matter much lighter than the flimsiest cloud. Now we must turn to our earth to examine by the aid of geology some of its history. The word " geology " is from two Greek words—*ge*, earth, *logos*, science—and the subject embraces all that can be known or inferred of our world.

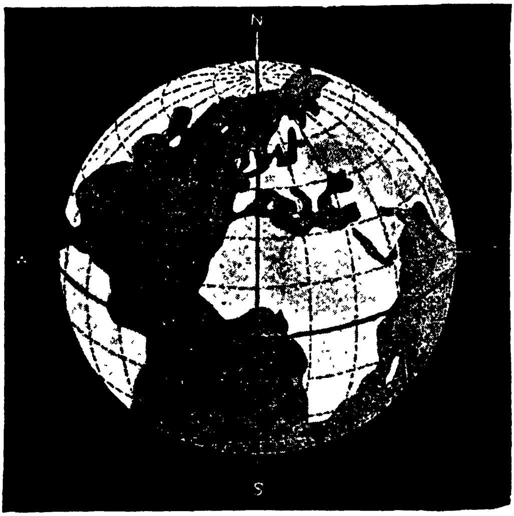


FIG. 48.—The Earth.

It is now generally admitted that, at a very early period, our globe was a molten mass—a thick liquid at a high temperature. As this mass swung in space, its surface cooled and solidified to form the crust of the earth. The " globe " (Fig. 48) is not exactly round, but like an orange with flattened ends, a fact that was discovered by Newton. If you place an orange on a table, the top will represent the North Pole, and the bottom the South Pole; the straight line joining the two poles represents the *axis*, and a circle around the bulge of the orange the equator. The earth does not rest on anything; it swings in space and turns round on its axis once every twenty-four hours at a rate such that a man standing on the equator is travelling at over 1,000 miles an hour. The circumference of the earth is about 25,000 miles at the equator; its diameter in the same region is nearly 8,000 miles. The short bipolar diameter is some twenty-six miles less.

The solid crust of the earth is about fifty miles thick. Whether in its earlier stages this was smooth or rough is not known, but we do know that at one period the earth was an unfurnished world, devoid of stratified rocks, water, plants, and animals. The materials now composing this crust are rocks of mineral matter of various kinds, as granite, sandstone, coal, clay, chalk. Some are hard, others soft, but, geologically speaking, all are rocks. Some of them, such as sandstones and limestones, always occur in parallel layers termed strata (Latin: *stratum*, anything spread out), and are therefore known as stratified rocks. These may lie almost flat, as in *A* of Fig. 49; or they may slope at an angle, as in *B*; or again, they may be bent into arch-like folds, as in *C*. When the ingredients

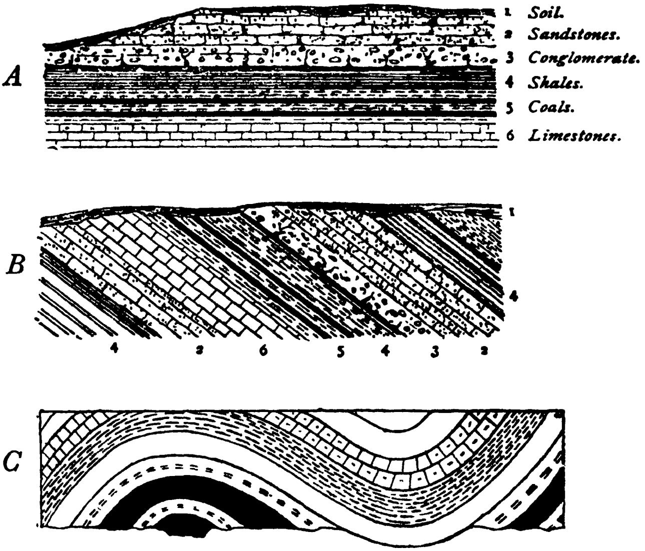


FIG. 49.—Stratified Rocks,

entering into the make-up of the stratified rocks are studied, they are found to resemble those of pebbles, sand, or mud, which at the present time are being brought together and deposited by the water in our rivers, lakes and oceans. The geologist, therefore, because the stratified rocks are formed through the action of water,

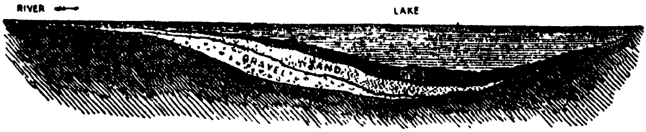


FIG. 50.—The Floor of a Lake after a Flood.

calls them aqueous and sedimentary rocks (Latin: *aqua*, water; *sedimentum*, a settling).

You can see the order of arrangement of the sediments in Fig. 50; reading from the top, we have mud, sand, gravel.

Vast masses, even mountains, of rocks exist of quite a different character; such are the granites, basalts, etc. As these are irregular and have no layers, they are known as unstratified rocks. They have no regularity of position or of arrangement and often occur among the stratified rocks, which they pierce through or even overlie in broad, vast masses (Fig. 51). The lighter-coloured layers (*a*) are the stratified rocks, and among them the dark masses represent (*b*) the unstratified. As these latter resemble in their composition and arrangement the material poured out by volcanoes, geologists ascribe them to the same agency—namely, the heat of the earth's interior—and call them igneous rocks (Latin: *ignis*, fire). In Fig. 52 we see the Giants' Causeway in Ireland where once lava was poured out and, cooling under great

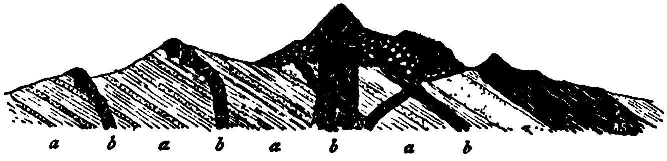


FIG. 51.—*a*, Stratified; *b*, Unstratified Rocks.

FIG. 52.—Basalt (the Giants' Causeway). *E.N.A.*

lateral pressures, split into pentagonal and hexagonal columns, which in olden days were thought to be the work of giants and demons.

The stratified rocks alone contain fossils, and thus are of importance for our purpose. We have seen that they were formed principally through the agency of water. Had the early crust been subject to no modifying causes, it would have remained in its simple, bare, early condition; there would have been no change of surface, no succession of plants and animals, and no stratified rocks. But owing to the revolution around the sun of the earth and its rotation about its own slanting axis, and the revolution around the earth of the moon, there has been introduced a succession of modifying agencies—day, night, summer, winter, heat, cold, winds, rains, rivers, waves, currents, tides, frosts, and glaciers—and the consequent periodical rhythms in plant and animal life. Again, the interior of our globe is a vast reservoir of heat, the effect of which is seen in hot springs, geysers, volcanic eruptions, earthquakes, etc. By the combined agencies of these forces ceaselessly operating within and around the earth, its crust is being continually altered, the old rocks crumbling away to sand while new ones arise.

All the known facts concerning the constitution, density, and elasticity of our globe are consistent with an interior composed of a mass of molten minerals. However, here we are dealing only with the crust of the earth, and this, we have seen, is exposed to so many powerful forces that it is never at rest. One result of these forces is the formation of a third kind of rock, the metamorphic, which is moulded under great heat and pressure out of stratified or unstratified rocks. Common slate is a good example of a metamorphic rock.

As far back as 1799 William Smith, at the age of twenty, noticed that the series of animal and plant fossils succeed one another in regular order, and that their type affords a means of identifying the strata. Fig. 53, showing the ideal "pillar of the rocks" of the earth's crust, is not drawn to scale and therefore does not convey an adequate idea of the vast depths of the pre-Cambrian formations. To correct this, the thickness in feet and the age in millions of years of the strata are given. The thickness stated is the maximum known and the ages quoted are based on evidence afforded by the radio-active minerals (thorianites, uranites, etc.) contained within certain of the rocks. The estimates are given on the authority of Dr. Arthur Holmes, Professor of Geology at the University of Durham. When Lord Kelvin gave a limit of 1,000 million years as the time during which the physical state of our globe might have permitted of life, his fellow-physicists were loth to allow geologists so much time for the evolution of animals and plants. The pendulum has now swung to the opposite extreme, and the modern physicists' grant of 1,500 million years as the span of life-potentiality more than justifies Kelvin's estimate. Surely, after this, we shall hear no more of the old difficulty, that there has not been sufficient time for the many species to arise.

Before entering into details we will learn the general characters of the fauna whose fossils figure in divisions in this pillar (Fig. 53). Beginning with the ancient rocks, the division above the lowest black line, we learn

ERA	EPOCH	DEPTH, IN THOUSANDS OF FEET		AGE IN MILLIONS OF YEARS		IDEAL LAYERS OF STRATA	BEDS DEPOSITS ETC.	DOMINANT FAUNA AND FLORA
		FOR EACH EPOCH	SURFACE TO BOTTOM OF EPOCH	FOR EACH EPOCH	SURFACE TO BOTTOM OF EPOCH			
ANTHROPOZOIC	HOLOCENE	·25	·25	·02	·02	▤	PRESENT HISTORIC NEOLITHIC	MAN
QUATERNARY	PLEISTOCENE	3·75	4	·98	1	⋯	PALÆOLITHIC GLACIAL	
CAINOZOIC OR TERTIARY	PLIOCENE	13	17	7	8	▨	NORFOLK NORWICH AND LENHAM BEDS.	MAMMALS AND MODERN FLORAS
	MIOCENE	14	31	12	20	▧	TORTONIAN HELVETIAN LIMESTONES.	
	OLIGOCENE	12	43	15	35	▥	HEMSTEAD BEMBRIDGE OSBORNE	
	EOCENE	20	63	25	60	▤	BAGSHOT LUTETIAN ALUM BAY LONDON CLAY.	
MESOZOIC OR SECONDARY	CRETACEOUS	44	107	50	110		MONTIAN CHALKS GREENSANDS WEALDEN PURBECK	REPTILES AND HIGHER FISHES
	JURASSIC	8	115	30	140	▦	PORTLAND CLAYS CALLOVIAN OOLITES CHELTENHAM LIAS, BLUE ETC	
	TRIASSIC	17	132	40	180	▥	LIAS, WHITE SANDSTONES	
PALÆOZOIC OR PRIMARY	PERMIAN	12	144	25	205	▨	LIMESTONES RED SANDSTONE.	AMPHIBIANS LYCOPODS AND PRIMITIVE FISHES
	CARBONIFEROUS	29	173	80	285	⁘	COAL MILLSTONE GRIT LIMESTONES	
	DEVONIAN	22	195	45	330	▧	OLD RED SANDSTONES.	
	SILURIAN	15	210	40	370	▤	LUDLOW WENLOCK LLANDOVERY TARANNON	
	ORDOVICIAN	17	227	78	448	⋯	CARADOCIAN LLANDEILIAN ARENIGIAN	
	CAMBRIAN	26	253	77	525	▥	OLENEIDIAN PARADOXIAN OLENELLIAN.	HIGHER INVERTEBRATES
PROTEROZOIC	UPPER PRE-CAMBRIAN	90*	343*	325	850	▦	KEWEENAWAN ANIMIKIAN HURONIAN ALGOMIAN SUDBURIAN	LOWER INVERTEBRATES
ARCHÆOZOIC	LOWER PRE-CAMBRIAN	90*	433*	400	1250	▨	LAURENTIAN GRENVILLE	UNICELLULAR PLANTS AND ANIMALS
AZOIC		?	?	1250	2500	▥	IGNEOUS MOLTEN GASEOUS	COLLOIDS, WATERY SOLUTIONS OF SALTS AND GASES VAPOURS AND GASES

FIG. 53.—General Table of the Earth's Strata and Geological Time-Scale. (After *Arthur Dendy, F.R.S., Arthur Holmes, D.Sc., F.G.S.*, and "*British Museum Guide to Department of Geology and Palæontology.*")

* Uncertain, but depths are *at least* as stated.

that they contain but the merest traces of a few classes of living things. Working our way upwards from the bottom of the pillar, we learn that the vast divisions of rocks called the *Primary* contain fossils belonging to genera and species usually distinct from those of the present day.

The *Secondary* era yields fossils, all of extinct types but more or less allied to recent forms.

The plants and animals represented in the *Tertiary* era belong partly to existing and partly to extinct species.

The *Quaternary*, Anthropozoic, or Recent, era comprises the formations still being deposited, and these contain, broadly speaking, the remains of plants and animals identical with those alive to-day.

To return to the bottom of the pillar, the rocks as far as the top of the Ordovician are characterized, for the most part, by small marine animals in shells, in a wide sense *Molluscs*. But in the Ordovician, armoured fishes begin to appear. Above the Ordovician comes the Silurian, which, with the next higher, or Devonian, division is known as the age of fishes. It would be difficult to over-rate the importance of these three periods, for they witnessed the origin of the first vertebrates (Ordovician), the rise of the lung-fishes from which all terrestrial vertebrates have probably sprung (Silurian), the first amphibians (Devonian), and the first invasion of the land by vertebrates (Devonian).

The Carboniferous period marks the age when enormous plants flourished and coal-beds were formed. Here, too, are huge sharks and lung-fishes. This was the age of *Amphibians*, including the great scaled and " roof-headed " types from which the reptiles and mammals sprang.

The Permian shows the end of Trilobites; but fish are plentiful, amphibians abound, also lizards of many kinds; as well as spiders, scorpions, centipedes, primitive insects, and snails. It was the harsh climate of these times, consequent on periodic glaciations, that compelled the primitive insects to develop those larval adaptations that enable them to tide over the cold spells in the resting conditions of *pupa* and *chrysalis*.

The next great division, the *Secondary* or Mesozoic, is known as the age of reptiles. Some of these grew to a huge size, others took on a bird-like form.

In the Triassic age the first mammal, a sort of duck-mole, appeared.

Reptiles were dominant in the Jurassic age, though many of them did not attain their zenith until the next or Cretaceous age. Primitive mammals were now abundant; in fact all the land vertebrates, as well as the higher fishes, were on the increase, although the archaic fishes, especially the sharks and rays, were on the down grade.

In the Cretaceous or chalk period, the highest order of fishes (*Teleosts*) and wading birds *with teeth* adapted for holding fish were coming into prominence. The great reptiles, some of which, such as Diplodocus, weighed twenty tons or more, were still dominant and had become highly specialized. Ichthyosaurs, Plesiosaurs, and Mosasaurs ruled the seas, the last even invading the abysses; Pterosaurs had conquered the air; and huge, fierce, carnivorous Dinosaurs lorded it over the land. Towards the close of the period, however, they all suddenly became extinct.

We now pass to the *Tertiary* rocks. Here the Vertebrates were essentially similar to those of the present day. All the existing sub-orders of fish were found; but the greatest change occurred in land Vertebrates, for mammals suddenly became the dominant type.

Most important of all, there arose at the base of the lowest or *Eocene* division of the Tertiary group, two genera, whose names, when translated, are the flesh-toothed (Creodonta) and the knuckle-jointed (Condylartha)—the ancestors of the Carnivors, Insectivors, and hoofed animals of the present day. In the upper part of the *Eocene* occurred placental mammals, among which were the primitive horse (Eohippus), lemurs, and marmosets.

In the *Oligocene*, or next higher part of the Tertiary, there occur cats, also certain animals intermediate between dogs and bears, the early horses Meso- and Mio-Hippus, Mastodons, and the first monkeys and apes.

In the third part of this division, the *Miocene*, the mammals, both in number and kind, reached their culmination. Browsers were succeeded by grazers, and both horses and elephants made great progress.

In the fourth or highest part of the *Pliocene*, occur the order of cats to which our domestic cat belongs, antelopes, pigs, apes, and man-apes. It was in this period that man-ape became man.

We now reach our topmost division, the *Quaternary*. It is divided into the *Pleistocene*, or great glacial period, and the *Recent*. Towards the close of the preceding Tertiary period, the climate became gradually colder, and with the beginning of the Quaternary there set in those periodic glaciations that spread over Northern Europe and North America. In Europe alone the ice is computed to have covered 770,000 square miles, and in places to have been 6,000 feet thick. On the Scottish mountains there are marks of the ice-sheet at heights of 3,000 feet and more. This enormous mass of moving ice overwhelmed the fauna of many districts, and so preserved for us relics by which we are able to reconstruct the long and interesting history of the earth's inhabitants, among whom were the sturdy men of the ice age.

Geology is a science dealing with so many millions of years that the mind is baffled in trying to grasp the time involved. Low forms of living things that were little more than specks of jelly seldom left any record in solid rocks under a pressure of many tons; in most instances where fossils have been found they are the remains or impressions of animals that possessed shells, bones, or scaly coverings; and of these we invariably find the more evolved forms in the uppermost rocks, and the simpler and less evolved in the lower rocks. Thus, we have to trace the rocks up from the bottom through layers representing millions of years before we meet with a *vertebrate*; and this, as we should expect, is a fish. We must then search through the higher rocks for further millions of years before we meet with a reptile, mammal, or bird.

The whole of the evidence of the rocks is in flat contradiction to the supposition that all animals, or even the same groups of animals, were made at the same time. The facts that races of animals and genera of plants have become extinct, that species of both which survive through long periods become so changed that they have to be classified as new species, are utterly opposed to the account of the creation of animals as given in *Genesis*.

ARCHÆAN AND PRE-CAMBRIAN ROCKS

In the rocks before the Cambrian period very few true fossils have been found. Heat and pressure have so metamorphosed the Cambrian rocks that impressions made by living things have for the most part been obliterated. " Indirect evidences of the long process of life evolution are found in the great accumulations of limestone and in the deposits of iron and graphite which are considered proofs of the existence of limestone-forming

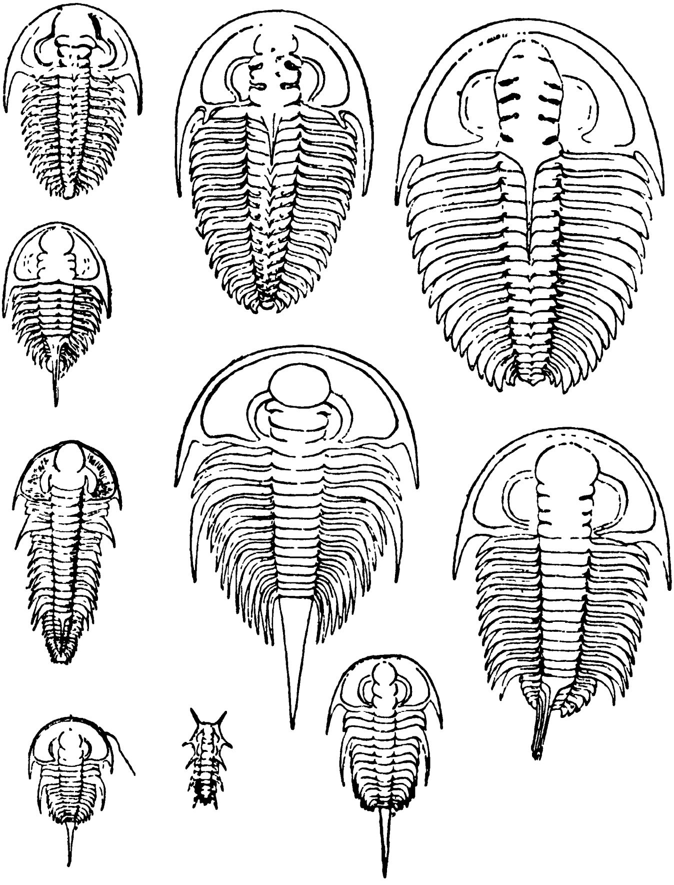


FIG. 54.—A Group of Cambrian Trilobites.

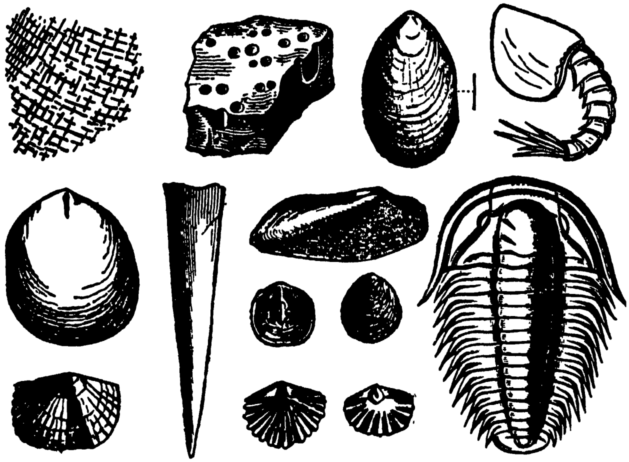


FIG. 55.—Other Cambrian Fossils.

algæ, of iron-forming bacteria and a variety of chlorophyll-bearing plants. *These evidences begin with the metamorphosed sedimentaries overlying the basal rocks of the crust of the primeval earth.*" (*After Osborn.*)

Working upwards once more from these Archæan formations to those of our own time, we will take a brief glance at some of the specimens we meet with at the various levels.

CAMBRIAN DIVISION

We begin with small shell animals from the sea; and the point to emphasize is how slow is the appearance of animals which at all resemble those living around us now. Fig. 54 and Fig. 55 show the most abundant animals of this early period; they are all, you will note, small, low forms, enclosed in shells.

SILURIAN DIVISION

In the Silurian division the Trilobites continue, though some have changed their form. Fig. 56 shows other life of the period.

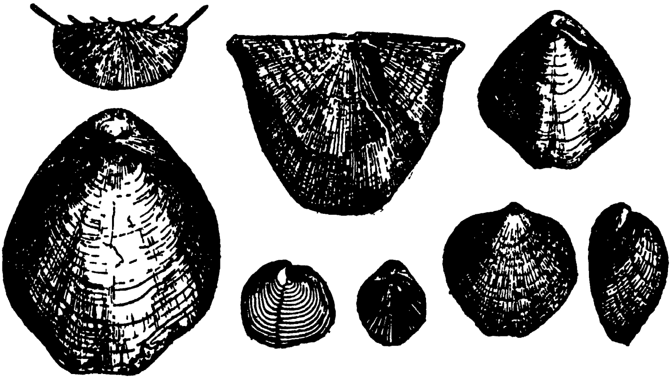


FIG. 56.—Upper Silurian Molluscs.

DEVONIAN DIVISION

Fig. 57 is from the Devonian or old red-sand-stone rocks. It is a vertebrate, but it has no jaws, and in this and other ways is probably allied to the lampreys; it is, in fact, a fish in the making.

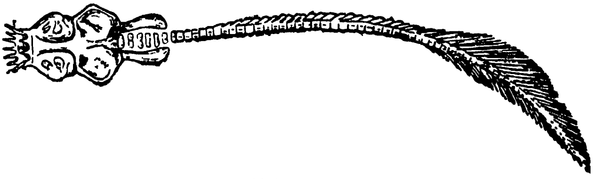


FIG. 57.—A Fish in the Making.

In Fig. 58 the one at the top and that in the middle are partly covered with bony plates. During this age fish were branching out in many directions, and forms resembling existing fishes were appearing. Sharks abounded, and Fig. 59 shows one of these ancient fishes. In Fig. 60 is a Crustacean, a member of a group that includes lobsters, crabs, cray-fish, shrimps, etc.

CARBONIFEROUS DIVISION

We have now reached the Carboniferous period when coal was formed through the deposit of an enormous and

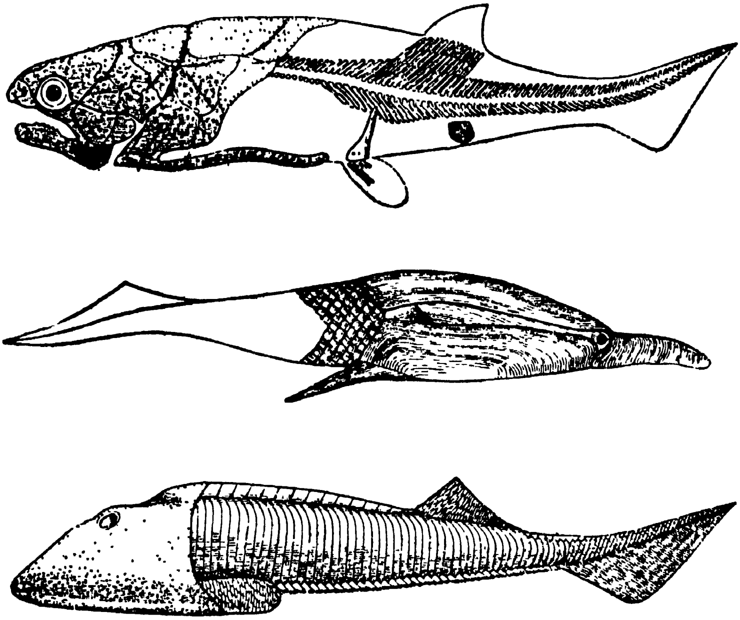


Fig. 58.—Three Early Forms of Fish.

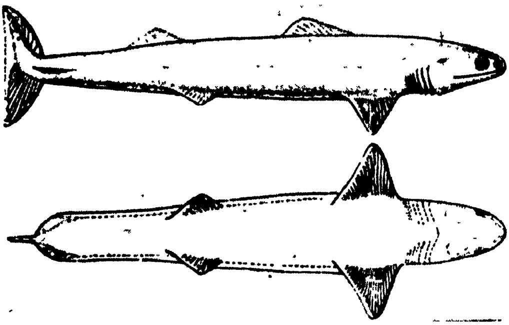


Fig. 59.—An Early Form of Shark.

abundant vegetation that then flourished. The small shell-covered marine animals continue, though under altered forms and as new species. Many orders of fish occur with more highly-developed structures, but the new marvels of this period are the stegocephalian or roof-headed *Amphibians*. In Fig. 61 you see the skull of one of these.

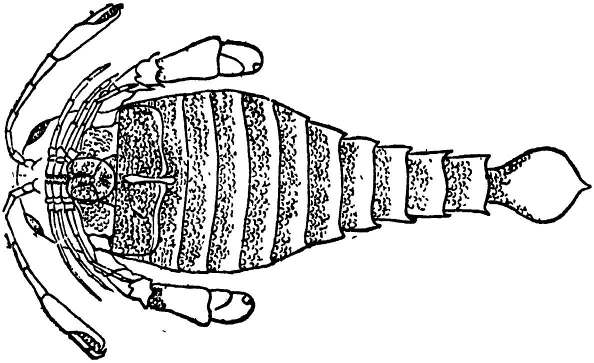


FIG. 60.—An Ancient Crustacean.

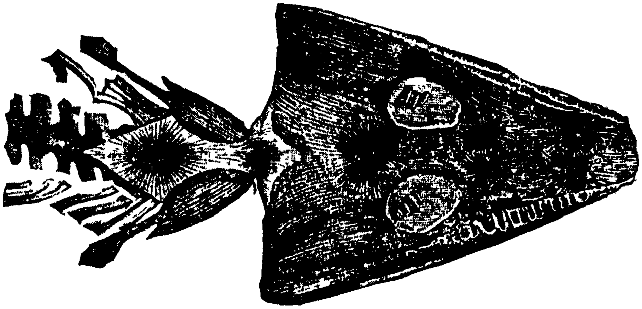


FIG. 61.—Archægosaurus.

PERMIAN DIVISION

Fig. 62 is a good representation of the same Amphibians as present in the Permian period. The utmost interest attaches to them, for from some of these animals came the reptiles which gave rise to mammals.

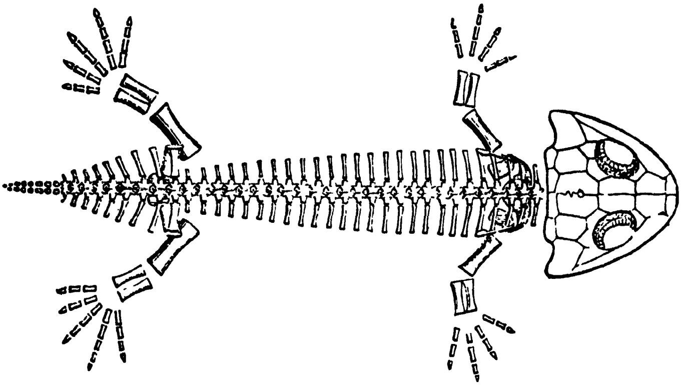


FIG. 62.—Branchiosaurus.

It is not to be supposed that these great divisions are marked off by some hard and fast line; the fauna of any one layer in a division merge with and closely resemble those of adjacent layers, but the fauna from layers that are well separated form distinct groups.

TRIASSIC DIVISION

We now pass from the Primary division to the Secondary. The lowest group of rocks in this division is called *Triassic*. They contain the remains of those reptiles which gave origin to the mammals. Fig. 63 shows one of the Theromorpha or mammal-shaped reptiles. Note what a crude, raw specimen it is.

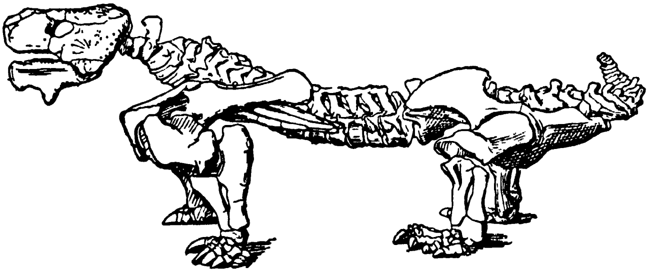


FIG. 63.—Pariasaurus Baini, from the Karoo, South Africa.

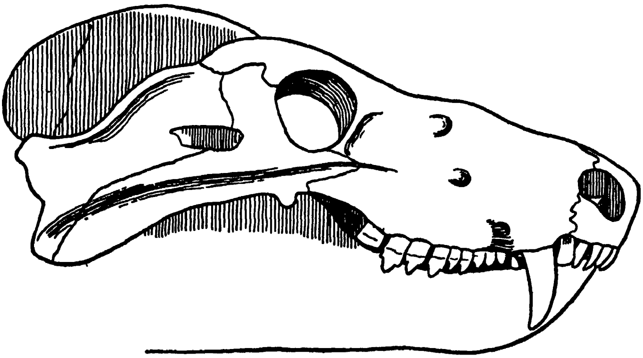


FIG. 64.—The Dog-jawed Reptile, Cyno-gnathus.

Fig. 64 shows the skull of a higher example of the group shown in Fig. 63; and Fig. 65 represents the skull of a weasel-like reptile. The top drawing gives a side view; beneath are upper and lower views of the skull with a tooth lying between. The appearance of this skull shows that the animal was as cruel and fierce as any of our carnivorous mammals.

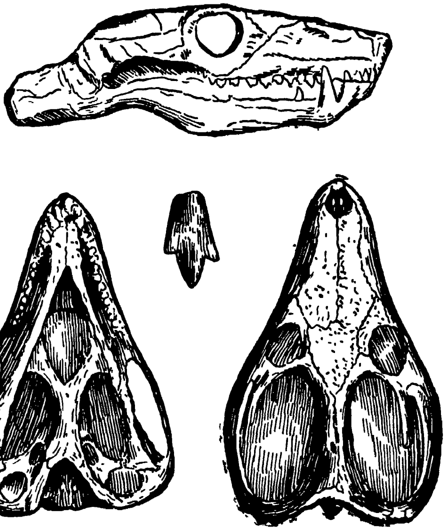


FIG. 65.—Skull of a Theromorph.

JURASSIC DIVISION

The next division of the Secondary rocks is called the *Jurassic*; its reptiles are noted for their huge size. By now they had conquered the land (Dinosaurs), the air (Pterosaurs), and the sea (Ichthyosaurs and Plesiosaurs).

Brontosaurus (Fig. 66) attained a length of 66 feet and a weight of 38 tons, but recently remains of reptiles which probably measured as much as 150 feet in length have been discovered. Megalosaurus (Fig. 67) is another of the gigantic animals for which this period is famed; and Fig. 68 shows a flying reptile. Some of them were very formidable in appearance, for example, Allosaurus had a cavernous mouth with a battery of saw-like teeth, while its hands and feet terminated in the tearing talons of some mighty bird of prey. But in this period there was unostentatiously appearing a small, simple type of warm-blooded viviparous animal that was destined to change the whole living order of the world. This was the first mammal, and, if alive now, we should probably class it as a very primitive kind of duck-mole, closely related to the pouched animals or marsupials. Birds with the tails and teeth of reptiles also appeared at this period.

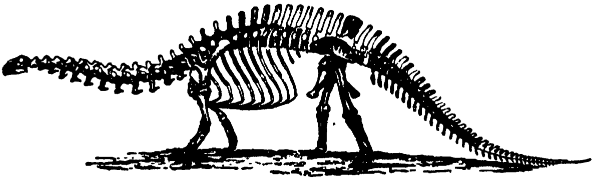


FIG. 66.—Brontosaurus.

CRETACEOUS DIVISION

The topmost division of these Secondary rocks is the great chalk age, called *Cretaceous*. This marks very little change from the preceding group.

Some of the great reptiles attained a zenith during this period and then rapidly disappeared. In America, about the middle of the Cretaceous, Nature, always red in tooth and claw, seems to have excelled herself in having

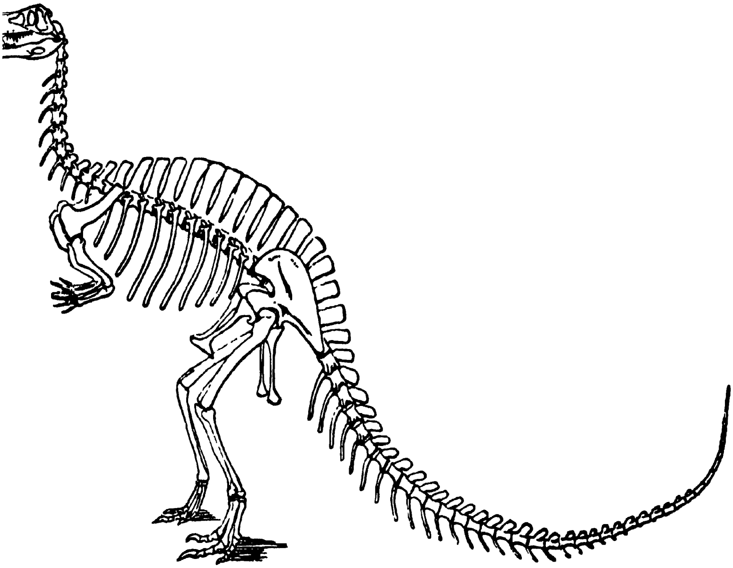


FIG. 67.—Megalosaurus.

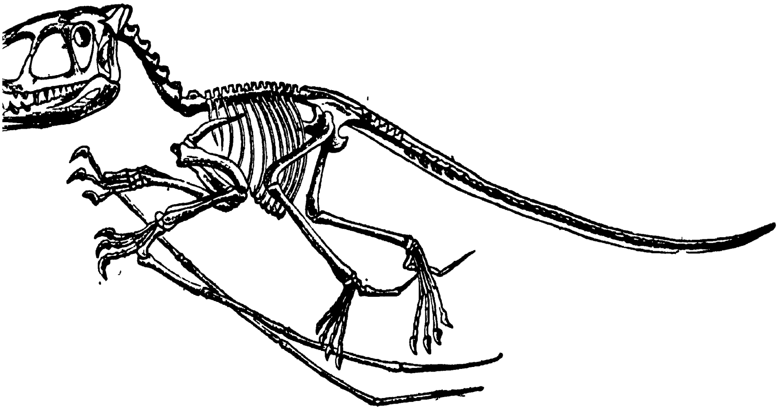


FIG. 68.—Dimorphodon, a Flying Reptile.

brought forth the most fiendish and diabolical living engine of destruction the world has ever seen and, let us trust, ever will see. This monster was *Tyrannosaurus rex*, arch-enemy of the harmless, unarmoured, bird-footed (*Ornithopoda*) dinosaur *Trachodon*, whose one hobby in life was munching horse-tail rushes. In his *Parade of the Living* Professor J. H. Bradley sums up the character and appearance of this creature in a way that should make its petrified ears tingle: " *Tyrannosaurus* came forth, the supreme climax of a sanguinary race. He was death in a living body, the largest and most horrible beast of prey the earth has ever seen. Forty-seven feet of powerful flesh had been built into a body heavier than that of even the largest elephant. Standing on massive hind limbs that supported his entire weight, he towered twenty feet above the ground. His head was more than four feet long, three feet deep, and nearly three feet wide. His jaws were set with daggers three to six inches long, and on his toes were claws as long as a man's hand. . . . For more than one hundred million years muscle was the measure of success, and by that measure *Tyrannosaurus* was easily king." Fig. 69 is certainly a very different type of dinosaurian reptile, and, though itself doomed to extinction, may have been one of the animals which were aiding the incipient mammals slowly but surely to oust from their overlordship of the American Continent the gigantic, beast-footed (Theropoda) dinosaurians. Many of these latter, it is thought, met their end through getting impaled upon the horns of Triceratops.

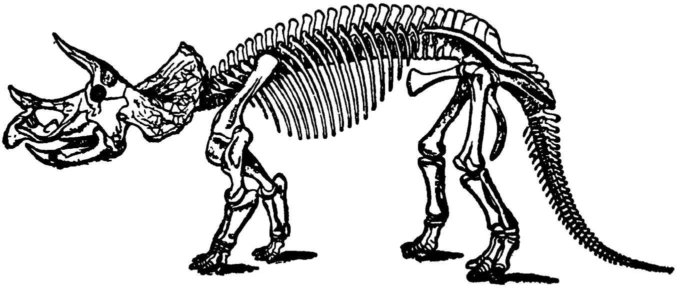


FIG. 69.—A huge armoured three-horned dinosaurian reptile, Triceratops.

Figs. 70 and 71 are two of the half-reptile-half-bird animals of this period. They have points resembling the lizard, and also, as you see, teeth. Many primitive mammalian forms were now coming on to the stage, several of them small, pouched creatures; others were allied to the duck-mole; while yet others may have belonged to the order of insectivorous animals.

We pass now to the third great division of rocks—the *Tertiary*. Here a striking change in the fauna has been brought about by corresponding changes in the crust of the earth. A great, massive, uniform formation, like the chalk which had been deposited in the sea, has given place to thin beds of sandy, shaly, or calcareous rocks. The large orders of huge reptiles have practically disappeared, and where the bed of the sea used to be

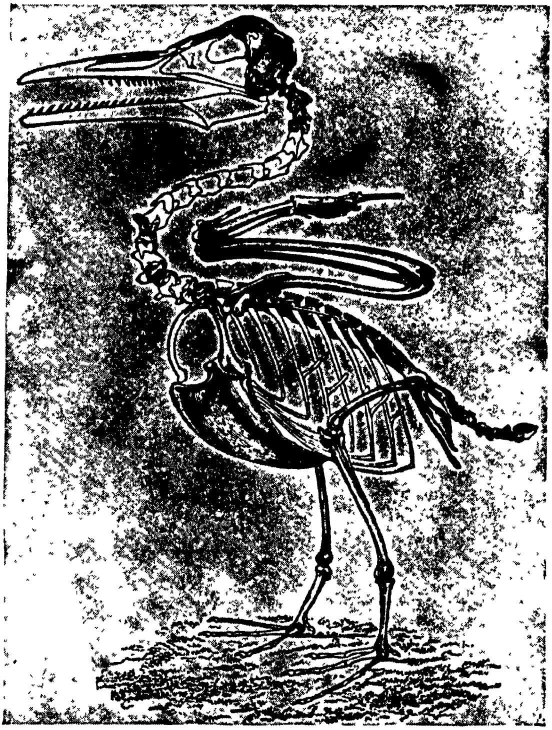


FIG. 70.—Ichthyornis Victor (Restored).

are now millions of square miles of dry plains over which roam animals such as the world had never seen before. Hence this period is called the New-life or Cainozöic. Crocodiles, sea-snakes, tortoises, and turtles are now the sole survivors of a great class that once ruled the world.

EOCENE DIVISION

In the lowest group of this division, the *Eocene*, we find the dominant animals are mammals.

Coryphodon was an animal rather like the modern tapir, while Hyracotherium (Fig. 72), the most ancient known equine of the Old World, had a shape inter-

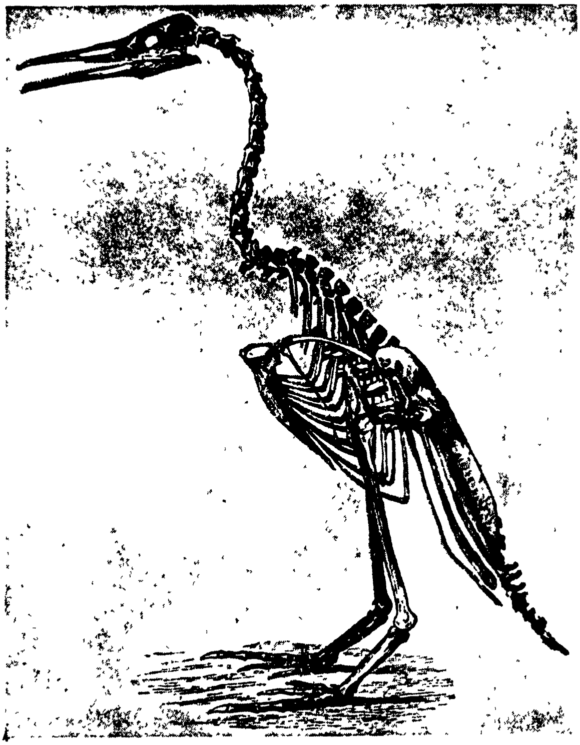


FIG. 71.—Hesperornis Regalis.

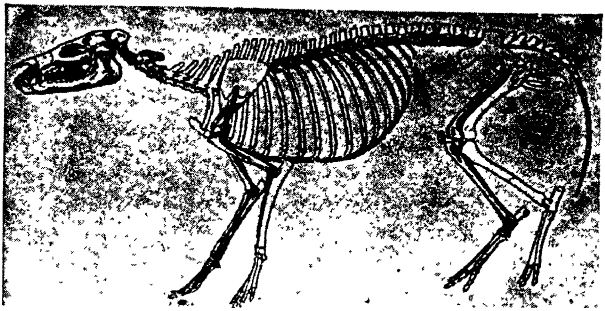


FIG. 72.—Hyracotherium, the most primitive horse known.

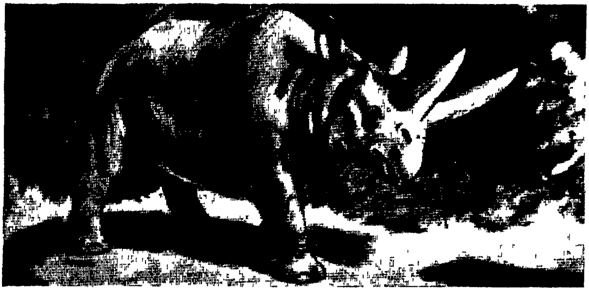


FIG. 73.—Arsinoitherium, of Lower Oligocene, a rhinoceros-like animal but with the two horns placed laterally. Discovered by H. J. L. Beadnell, F.G.S., in the Fayum Desert, N. Africa.

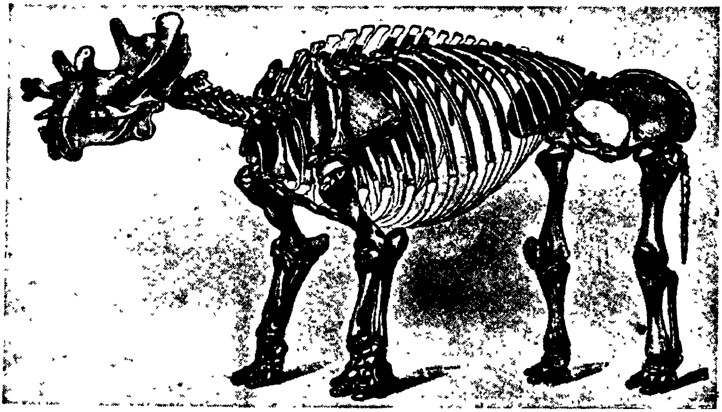


FIG. 74.—Tinoceras, a huge six-horned, two-tusked mammal of the Eocene, the last of its race.

mediate between the hog and the Hyrax. Tinoceras (Fig. 74) belongs to a group remarkable for its tiny brains yet massive heads. These animals were as big as elephants, had the habits and stupidity of rhinoceroses, and bore three *pairs* of horns—two on the snout, two on the forehead, and one on each cheek.

Not only are insectivorous animals found in the Eocene, but also several small animals of the lemur type, such as Adapis (Fig. 75), the earliest representatives of the Primates.

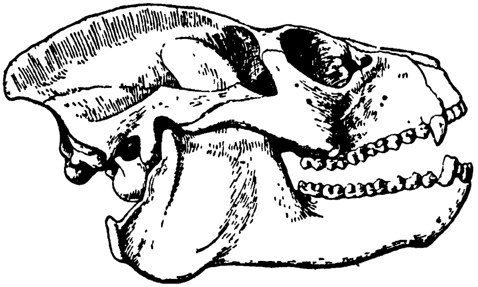


FIG. 75.—Skull of Adapis.

OLIGOCENE DIVISION

The *Oligocene* plays but a subordinate part in England, being only in evidence in parts of Devonshire and Hampshire. Elsewhere, however, the period swayed considerably the course of evolution. An increasing aridity of climate (that culminated in the Miocene) and a general uplifting of the dry land entailed the replacement of the tropical and sub-tropical forests by deciduous trees, and of marshlands, lakes, and streams by vast prairies. Leaf-eating animals were cut out in the struggle for existence by the grass-eaters; while the Primates, which received such a good " send off " in the Eocene, met with a severe rebuff through winter curtailing their hitherto continuous fruit food supplies. Speaking generally, the period was one of mammalian advance, especially of the earlier forms of the camel, horse, elephant, and rhinoceros. One of the last (*Arsinoitherium*) is shown in Fig. 73.

MIOCENE DIVISION

Elotherium (Fig. 76) is a large, pig-like animal, which, you should note, had learnt to walk on its toes. It is found in the Miocene of Europe and North America.

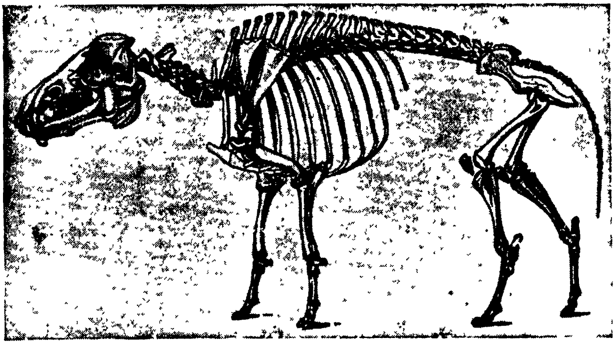


FIG. 76.—Elotherium.

The Mastodon (Fig. 77) has now appeared, but not until the next period does its cousin, the Elephant proper, come on the scene. Both these creatures were offspring of the Miocene *Trilophodon*, and grandchildren, so to speak, of *Palæomastodon* of the Oligocene, and great-grandchildren of the little Eocene *Moeritherium*.[1]

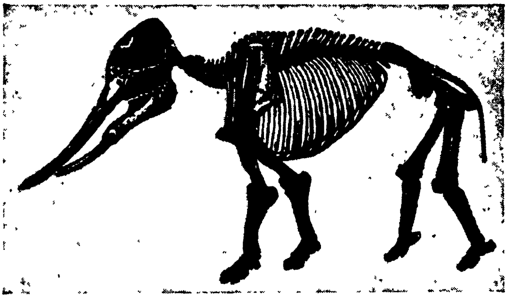


FIG. 77.—Mastodon.

---

[1] The remains of *Moeritherium* (Upper Eocene) and *Palæomastodon* (Lower Oligocene), lying in fairly close proximity north of the site of the ancient Lake Moeris in Africa, were first discovered by H. J. L. Beadnell, F.G.S.

The wonderful flesh-toothed animals (Creodonta), ancient Carnivors, appear for the last time in the Miocene.

The middle Miocene is remarkable for a series of genera intermediate between dogs and bears, and also for *true apes*.

PLIOCENE DIVISION

We next come to the uppermost group of rocks in the Tertiary division, called the *Pliocene*. By this time the mastodon is widespread and towards the end of the period the true elephant appears. Typical pigs have now replaced the pig-like forms.

Hipparion (Fig. 78) is one of the ancestral horses (though a cul-de-sac branch), which appeared and became abundant in the Miocene (only, however, to disappear in the Pliocene), but species of the true horse were also present.

PLEISTOCENE DIVISION

We have now looked at the series of animals from early Cambrian times to the beginning of the great ice age, as the *Pleistocene* period is often called.

True apes, which as we saw were already present in the Miocene of Europe, are now plentiful. Most Euro-

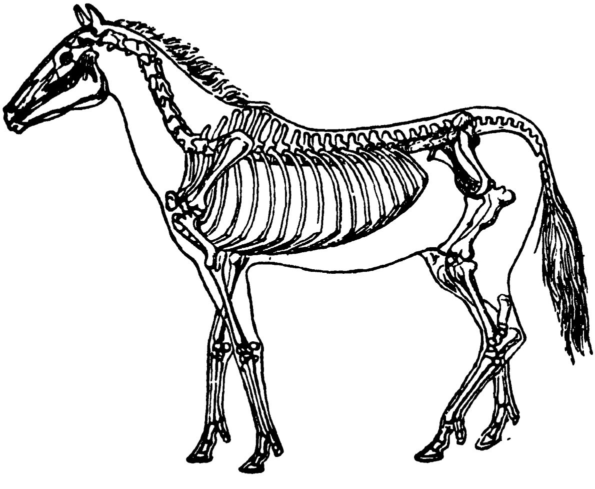


FIG. 78.—Hipparion.

pean fossil apes can be referred to the family Cercopithecidæ, which includes all those now living in the Old World, except the gibbons, orangs, chimpanzees, and gorillas that together form the Simiidæ. The oldest fragments found of apes are the jaws and teeth of a comparatively large specimen from the Middle Miocene of Tuscany. Fragmentary remains of apes are known from the Pliocene and Pleistocene of India, the most interesting being typical portions of the dentition of baboons (Cynocephalus), which are now restricted in their range to Africa and Arabia. Fig. 79 depicts the skeleton of Mesopithecus, a Pliocene ape unearthed at Athens. Other Pliocene apes have been disinterred at Montpellier (Macacus), and in France, Italy, and Asia (Semnopithecus).

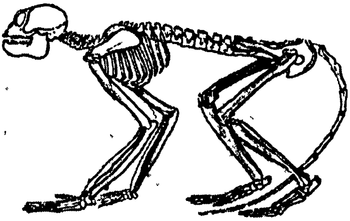


FIG. 79.—Mesopithecus.

The oldest known traces of a man-like skeleton are an imperfect roof of a skull, three teeth, and a thigh-bone, found, together with the remains of Pliocene mammals, near Trinil, Java, by Dubois in 1891. This creature, a humanoid representative of a side-branch of the true human stem culminating in present-day man, was named *Pithecanthropus erectus*, for it walked on two legs, like man. Keith and Elliot Smith are agreed that the part of the brain corresponding to that which in ourselves governs speech, though small, was sufficiently developed to allow of a primitive kind of talking.

" The oldest human skeletons of which the geological age can be determined with certainty are two from the cavern of Spy, near Namur, in Belgium. These were

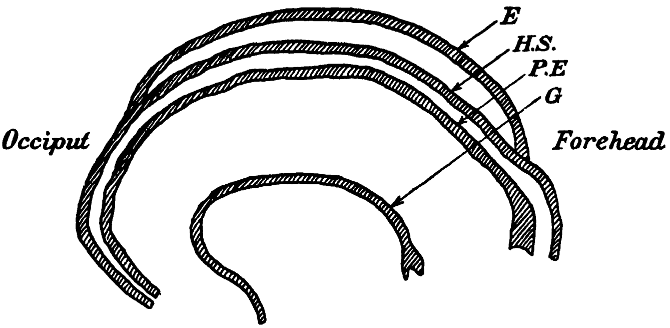


Fig. 80.—Outlines of skulls of the gibbon ape (*G.*). *Pithecanthropus erectus*, the Ape-man (*P.E.*), *Homo Sinanthropus*, Peking Man (*H.S.*), and a modern European (*E.*) (Modified from *Keith*).

found in association with remains of the mammoth and other Pleistocene mammals beneath a layer of stalagmite which had never been disturbed. They are essentially human in every respect. They represent a race small but powerfully built. The forehead is low, the supra-orbital ridges are very prominent, and the chin is remarkably retreating. The leg cannot have been quite upright in walking. This type is known as the *Neanderthal race*, other similar fragments having been found in 1857 in a cavern in the Neanderthal between Düsseldorf and Elberfeld, Germany" (*Woodward*). New human remains are found every few years, and some of these are held to be even earlier than the Java ape-man. The Piltdown skull (Eoanthropus, the Dawn-man) is about 400,000 years old. Many others besides the above-mentioned are now known, and their general relationship to living races of mankind on the one hand and to living and extinct apes on the other, as well as their estimated age, may be gathered from the genealogical tree on pages 9 and 258.

Fig. 80 shows the skull of Pithecanthropus compared with those of a gibbon ape, Peking Man, and a modern European.

We may fitly close this chapter with an example that sustains the doctrine of evolution in an unmistakable manner. The remarkable series of shells of a fresh-water mollusc of the Tertiary age shown in Fig. 81 exhibit almost insensible gradations; so much so, that, while the difference between any two adjacent specimens is scarcely discernible, that between extremes is so marked that the shells might excusably be considered to belong to distinct species; indeed, before the discovery of the numerous connecting links they were so regarded. It is easy, from such a series as this, to imagine how, by continued derivation and modification, new species of animals and plants have arisen. The illustration depicts the whole " origin of species " at a glance.

From such an illustration some idea may be formed of what constitutes the present evidence in support of evolution, and what that evidence will be when further links have been collected. The warning words of Dean Inge—" Those who take refuge in gaps will, sooner or later, find the gaps closing in upon them "—are proving true;

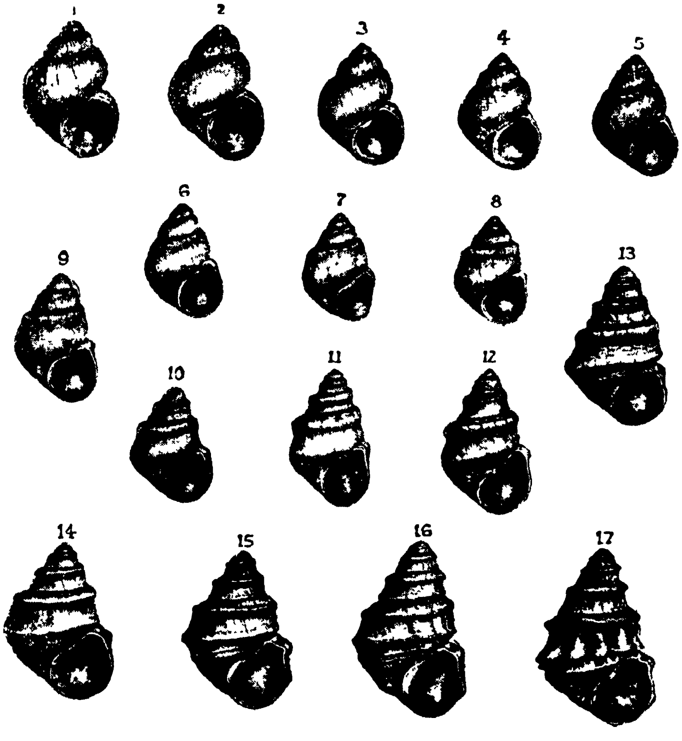


FIG. 81.—A Complete Series of Paludina.

many of the great gaps which existed have been filled up, while those that remain are being filled up. The evolutionist watches the process in calm assurance, for every discovery but adds further proof of the truth of his doctrines; *not one throws the least doubt on evolution.*

Sir Charles Lyell was perhaps the most eminent geologist alive when Darwin brought out *The Origin of Species*. Lyell had prepared the way for Darwin by showing in his *Principles of Geology* that there were none of those breaks called " catastrophes." But though Lyell and Lamarck between them had killed Cuvier's "catastrophic theory," still the former was not able at first to accept Darwin's explanation of the origin of species. At sixty-two years of age Lyell was still weighing the evidence; but, at long last, in 1867, when he brought out the tenth edition of his *Principles of Geology*, he proclaimed that he accepted evolution as true.

FIG. 82.—Sir Charles Lyell (1797–1875).

Such testimony from such a man, after eight years of the most cautious inquiry, at the ripe age at which culminated a career devoted to the study of the crust of the earth and its fossils, produced a sensational effect, for Wilberforce, the Bishop of Oxford, had relied especially upon Lyell to crush Darwin!

CHAPTER FOUR: ZOOLOGY (TO MAMMALS)

BEFORE evolution of any organism can take place there must be an environment more or less favourable to it. All organisms do not necessarily evolve in a straightforward manner to something higher and better; some take a zigzag course, others remain stationary, and yet others, after a brief forward advance, go back. While *all* living things are related one to the other, it is not true that every form of high plant or animal has come through *every* plant or animal *inferior* to it. Two brothers are closely related in virtue of the fact that each had the same parents, which biologically means that one germ-cell in the paternal and another in the maternal grandparent contained a common ancestral representative of both. In each of those germ-cells the two brothers were identifiable as a single entity. Again, two cousins are less closely related than two brothers, because the germ-cells in which each was represented as a single entity were one or more generations further back. Oak trees do not come from rose trees, but, if you could trace them far enough back, you would find some tree or shrub that was the ancestor of both. Some animals have developed on a main line; while others, for example, birds, have developed on a side line, but, though mammals and birds have come *from* reptiles, neither has come *through* the other.

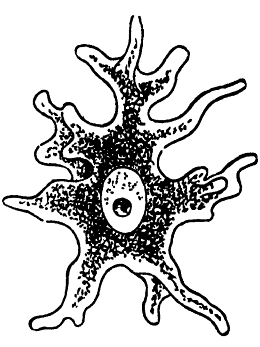


Fig. 83.—Amœba.

If we look at the animal world, as we find it in fossils and living forms, we shall learn that they are all one large family of near and distant relations. We will begin with one of the lowest forms of animal life.

The Amœba (Fig: 83) is found in the water of ponds and ditches. It is one cell, complete in itself, but so small that it is only visible through a lens. It has no organs nor parts, no limbs nor mouth; in the resting phase it is spherical, in the active phase it is constantly changing its shape—in fact, its name is derived from the Greek word for

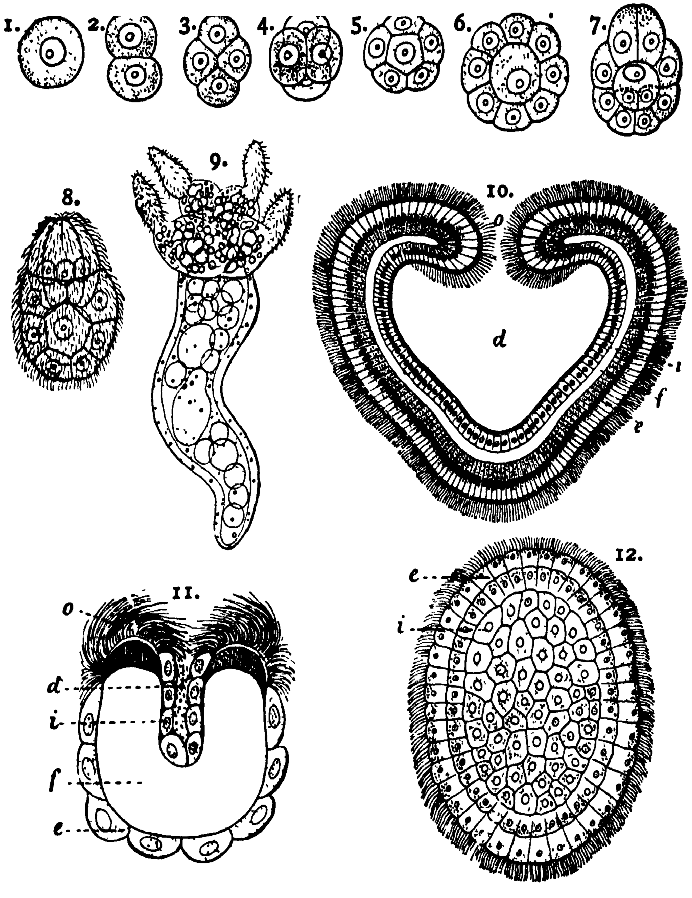


FIG. 84.—Modern Gastrula-like Animals or Gastræads.

1–9. Gastrulation stages of *Conocyema* from (1) the protozoal to (9) the mature gastræad form.

10. Section of the gastræad *Pemmatodiscus* showing primitive mouth, *o*, and gut, *d*.

11. Section of the gastræad *Kunsleria Gruveli* showing *o*, mouth ; *d*, gut; *i*, entoderm; *f*, blastocœl (the clear vesicle); *e*, ectoderm.

12. Planula, a ciliated larval form of Rhopalura. *e*, ectoderm; *i*, entoderm. The planula is an earlier stage of the gastrula.

change. It grows fast, and when it becomes so large that the surface can no longer take in enough food for the "inner man," it undergoes fission—that is, it simply tears itself into two. This fission is based on a well-known principle in physics, viz. that in an enlarging sphere the surface increases as the square of the radius, while the mass, or content, increases as the cube. Consequently when, in the growing amœba, the interior begins to get starved through failure of the surface to pass in enough food, it splits into two, thus once more restoring a favourable relation between the surface and the inside.

The next step in evolution was that the cells, instead of separating after division, clung together. The protozoa became the metazoa or many-celled animals. The very small animals in Fig. 84 have been greatly magnified, and they show clearly how, after dividing and redividing, cells remain attached to each other and so form a many-celled animal. Number 9 shows the full-grown animal, and you can trace its growth from the single cell (1) to the multi-cellular gastræad stage (8). All living things, including man, grow in this way.

Animals that have no bones, or internal skeleton, are known as Invertebrates—*i.e.* having no vertebræ or backbone. They are divided into many families—worms, snails, flies, etc. We are chiefly concerned at this point with the worm-like class, for in these animals was developed a tube inside the outer tube—hence their group-name, the Cœlomata, or hollow-bodied animals. Very soon the inner tube—probably because it was more sheltered and better fed—tended to grow longer than the outer one, so had to bend on itself, and this bending process continuing for millions of years eventually resulted in the many-looped intestines of higher animals. The earth-worm is a land animal in which we find a well-marked hollow body and a distinct blood system. It has a mouth at one end and a vent at the other, but being an Invertebrate, it possesses no bones.

We have now to look for the origin of the backbone. This took place in animals that lived in the water. Let us take a glance at Balanoglossus, the Acorn-worm (Fig. 85), a humble creature that burrows in the sand of the sea-shores between high and low tide marks. It is the most primitive member of the very large class of

Vertebrate or back-boned animals. Three features unite all this class; one is the structure called the *notochord*, a gristly rod running along the back; a second is the gill-slit openings in the front part of the food tube or alimentary canal, through which openings or " gills " breathing is effected; and a third feature is the presence of a nervous system which commences as a strip of sensitive skin cells along the back that, becoming rolled into a tube, ultimately forms the *spinal cord* and nerve canal. These three characteristics will enable you to determine whether an animal is a vertebrate or not. In Fig. 85 the gill-slits are marked 5; the " collar " is marked 2, and in this is a short notochord, which projects into the " proboscis," marked 1. In this collar is also found a primitive nervous system consisting of a small nerve-mass and nerve-ring that send respectively nerves forward into the proboscis and backwards along the body. Consequently we are entitled to place this worm among the Vertebrates.

Another member near the bottom of the vertebrate stem is the Sea-squirt, one of the Tunicates or Ascidians.

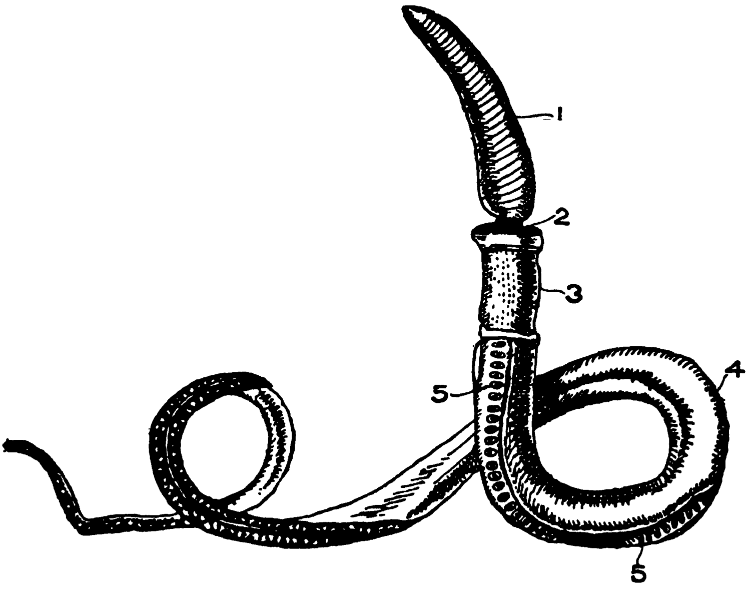


FIG. 85.—Acorn-worm (Balanoglossus).

The full-grown animal (Fig. 86) shows scarcely any trace of its vertebrate relationship. It is unable to move about and lives fixed to some support at the bottom of the sea. In Fig. 87 it will be seen how alike are the larvæ or tadpoles of the frog and Sea-squirt. In each of these larvæ there exists a notochord. This is shown in section in Fig. 88 as the faint, short line running through the tail below the black nerve-chord that extends throughout the whole length of the body to terminate in front in an enlargement that is the forerunner of the brain of higher Vertebrates.

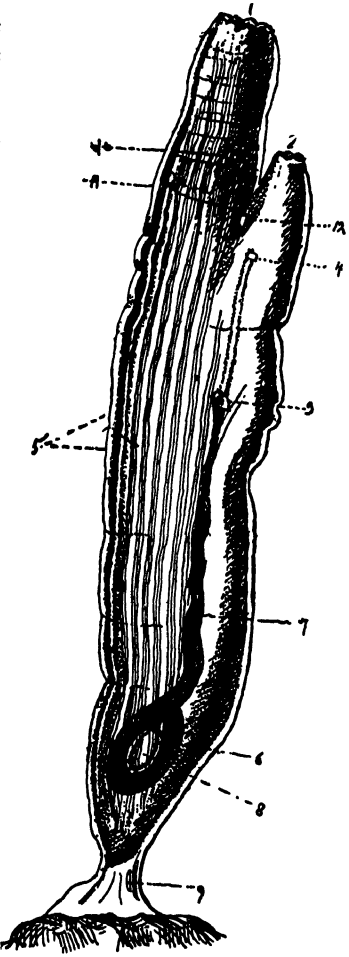


Fig. 86.—Sea-squirt.

1, mouth; 2, atrial orifice; 3, anus; 4, genital pore; 5, muscles; 6, stomach; 7, intestines; 8, reproductive organs; 9, stalk attached to rock; 10, tentacular ring; 11, peripharyngeal ring; 12, brain.

A third remarkable animal near the bottom of the Vertebrates is the Lancelet or Amphioxus (Fig. 89), a word meaning "pointed at both ends." This marvellous animal is found in the sandy shallows of the sea. It is from one to two inches long, has no "head" in the ordinary acceptance of the term, is nearly transparent, and possesses a stiffening notochord running the length of its body.

The Acorn-worm, the Sea-squirt, and the Lancelet are probably three surviving representatives of many ancestral forms from one or other of which fish may have arisen. All land Vertebrates, including, of course, our-

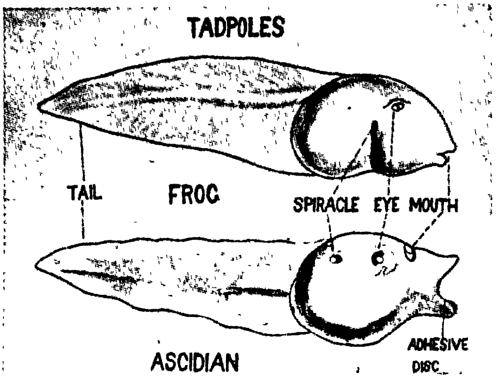


FIG. 87.—Tadpoles of Frog and Sea-squirt, or Ascidian.

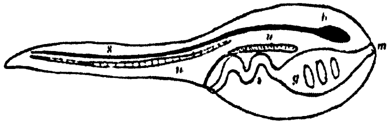


FIG. 88.—Tadpole Ascidian.

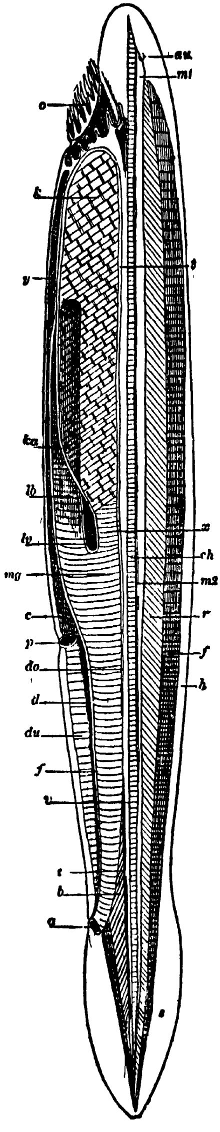


FIG. 89.—*Amphioxus Lanceolatus.* (After *Haeckel.*)

a, anus; *au*, eye; *b*, ventral muscles; *c*, body cavity; *ch*, notochord; *d*, intestine; *do* and *du*, dorsal and ventral walls of the intestine; *f*, fin seam; *h*, skin; *k*, gills; *ka*, gill artery; *lb*, liver; *lv*, liver vein; *m1*, brain bladder; *m2*, spinal marrow; *mg*, stomach; *o*, mouth; *p*, ventral pore; *r*, dorsal muscle; *s*, tail fin; *t*, aorta; *v*, intestinal vein; *x*, boundary between gill-intestine and stomach intestine; *y*, hypobranchial groove.

selves, have undoubtedly evolved from some form of fish. Fig. 90 shows the jointed bones or vertebræ of a backbone, in this case a human one.

Let us take a look at some of the fishes, the lowest group of true Vertebrates, so that we may have some idea of the vast variety of these animals.

Figs. 91 and 92 show the lamprey, a very low type of fish with a head scarcely marked off from the body.

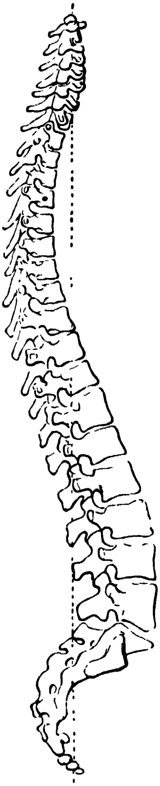


Fig. 90.—Vertebræ of the Human Backbone.

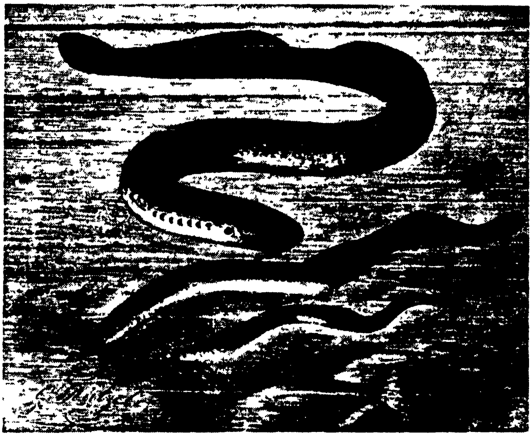


Fig. 91.—A Group of Lampreys.

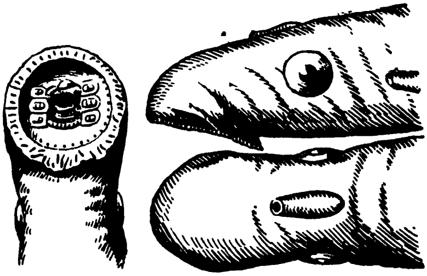


Fig. 92.—Head of a Lamprey.

The lamprey belongs to the class Cyclostomata or round-mouthed fishes. You may see in the lower of the two figures the round sucker by which the animal attaches itself to objects. These low, round-mouthed, jawless fishes, with a nose that is a mere sac, are put in a division by themselves to mark them off from the higher fishes which possess jaws.

The class Pisces (true fishes) is characterized by fins. The paired fins, from which have been evolved the four limbs of terrestrial vertebrates, are probably derived from the splitting up of two originally continuous lateral flaps.

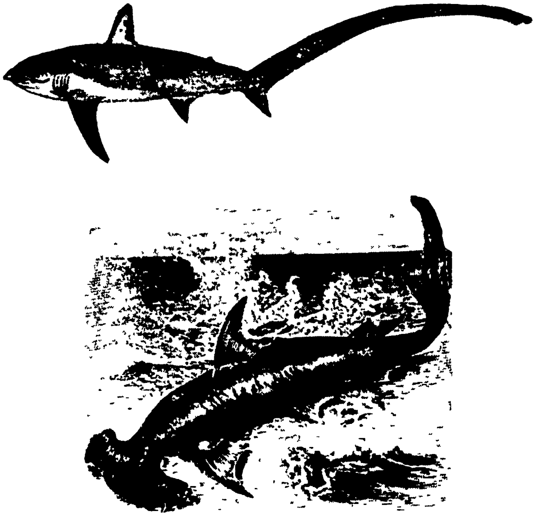


FIG. 93.—Thresher Shark and (below) Hammer-headed Shark.

Fishes are divided into three sub-classes:—

Elasmobranchii, Dipnoi, and Teleostomi.

The common ancestors of all the higher fishes were probably primitive shark-like types (*Elasmobranchs*).

Sub-class 1, the Elasmobranchs, contains Sharks (Fig. 93), Dog-fish (Fig. 94), Skates or Rays (Fig. 95), and the Holocephali (Fig. 96).

All the members of this old family exhibit a primitive stage of evolution, and, in common with the round-mouthed fishes, their skeleton consists chiefly of gristle or

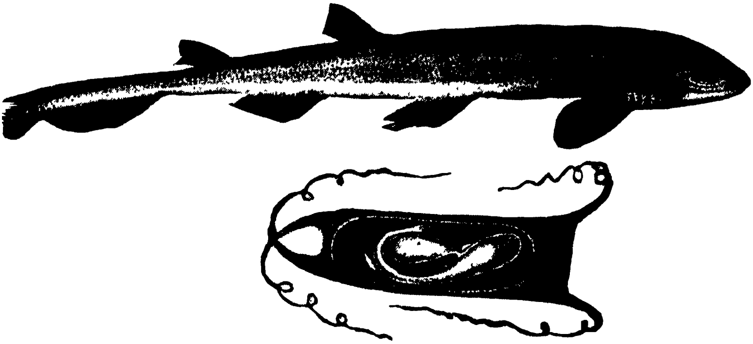


Fig. 94.—Mature Dog-fish.

(Below) An egg-case with its anchoring filaments (that automatically wind round a stalk of sea-weed) showing within an embryo dog-fish with its nourishing yolk-sac attached.

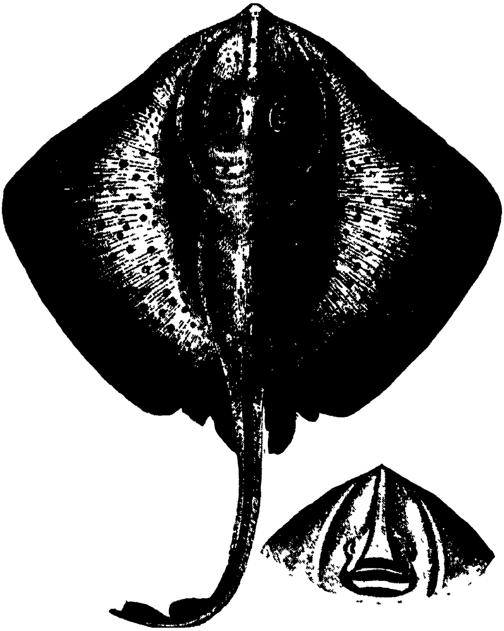


Fig. 95.—Skate or Ray. (Below, under surface showing mouth.)

cartilage, hence they are also known as the cartilaginous fishes.

The Holocephali are now represented by five families that include the *Chimæridæ* (Fig. 96).

Sub-class 2, the Dipnoi, Dipneusts or double breathers, sometimes called lung-fish, has only three living species:—

The Burnett salmon (Neo-Ceratodus), the Mud-fish (Protopterus), and the Lepidosiren (Figs. 97 and 98).

The Dipneusts breathe not only in the water by means of gills like ordinary fishes, but also in the air by means of *a lung or lungs*, and in consequence their blood-circulation differs from that of ordinary fishes. Neo-Ceratodus of Queensland has one lung, while both Protopterus of certain Central African rivers and lakes and Lepidosiren of the Amazon possess two lungs. All land animals have probably descended from some ancestral member, either of the Dipneusts or of a similar group such as the Crossopterygii, of which Polypterus of the Nile (Fig. 99) is a good example.

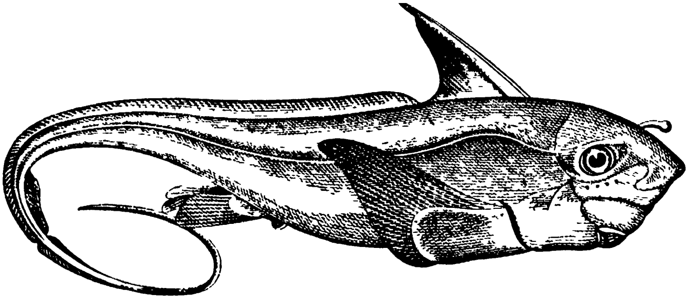


FIG. 96.—Rabbit-fish or Chimæra.

Sub-class 3, the Teleostomi, or perfect-mouthed fishes, is divided into two sub-orders:—

a. The Crossopterygii (the fringe-finned). There are only two living genera of this sub-order, Polypterus (Fig. 99) and Calamoichthys, which inhabit the rivers of Africa. In these fishes the air-bladder is occasionally used as a lung.

b. The Actinopterygii. This sub-order is divided into the Ganoids and Teleosts. The Ganoids figured very conspicuously in the past, the original stock arising in the Silurian and flourishing in the lower Carboniferous periods. From the ancient true Ganoids (as distinct from the lobe-finned Ganoids) arose the Sturgeons, Garpikes, Bowfins, and the huge group of Teleosts, which includes most of our best-known fishes such as the salmon, pike, herring, sole, perch, etc. There are perhaps ten thousand species in this division.

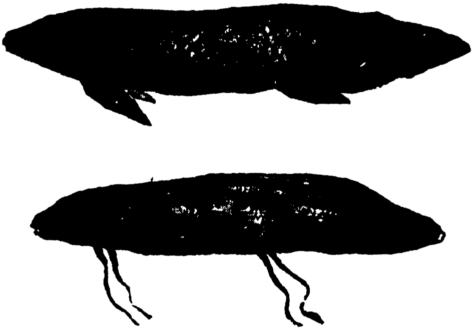


FIG. 97.—The Burnett Salmon (*Neo-Ceratodus*), and (below) the Mud-fish (*Protopterus*).

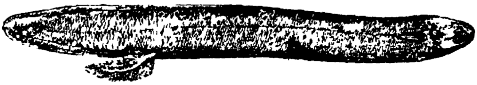


FIG. 98.—Lepidosiren.

The Blenny (Fig. 100) is very peculiar, in that the female *brings forth the young alive*, while the male constructs a nest in which the brood are lodged. The male of the uncouth-looking Lumpsucker, shown in the same

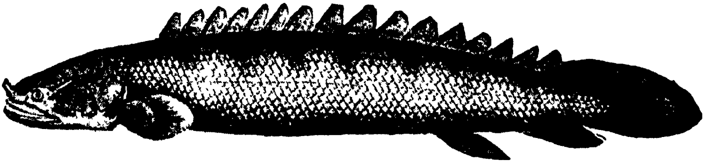


FIG. 99.—Polypterus.

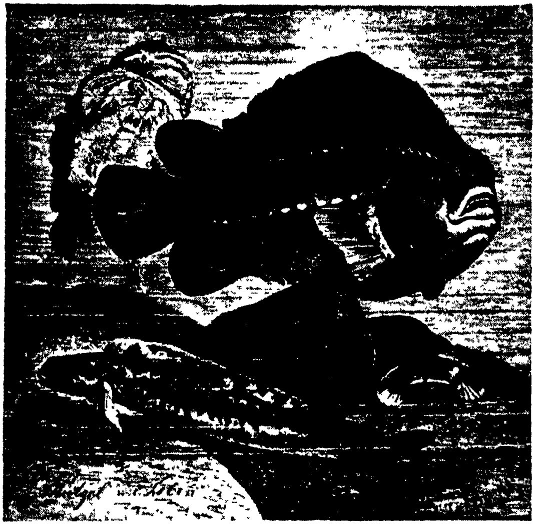


FIG. 100.—Lumpsucker and (below) Blenny.

figure, is also a good father, for he not only carefully guards the eggs, but allows the young to cling to his body with their suckers.

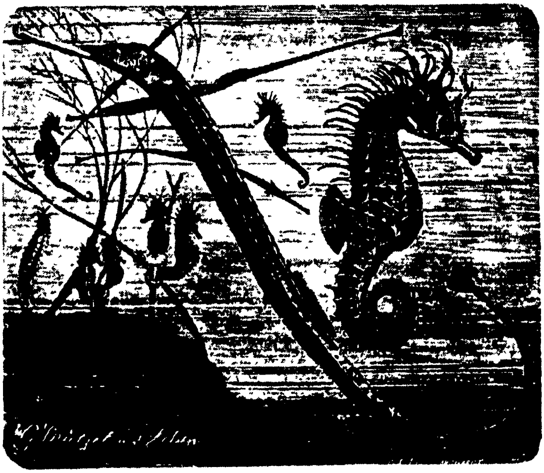


FIG. 101.—Sea-horses and Pipe-fish.

Male sea-horses and pipe-fish (Fig. 101) place the fertilized eggs of the female in a pouch on their abdomen inside which the young are hatched out.

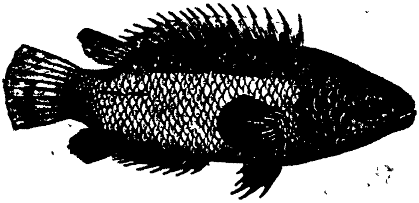


FIG. 102.—Climbing Perch.

The climbing perch of India (Fig. 102) wanders about on land, and has been known to climb low trees by means of the spines on its gill-covers and ventral fins. It has an accessory breathing organ in connection with the branchial arches. Fig. 103 shows a fish the name of

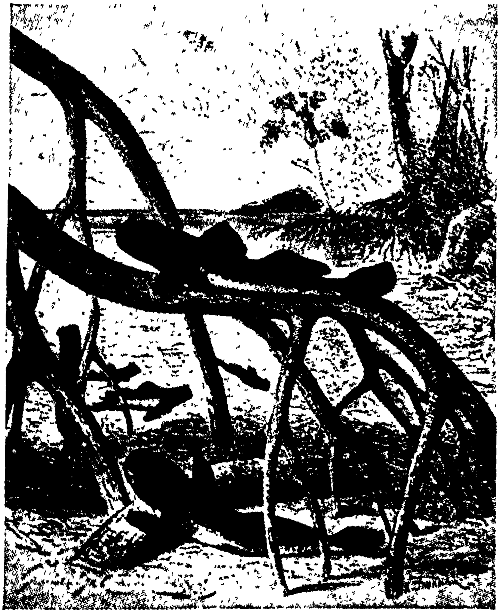


FIG. 103.—Goggle-eyed Periophthalmus.

which means "one who can see all round." Periophthalmus runs about actively over the mud-flats, and climbs up the roots and stems of mangrove trees in the estuaries of the Indian and Pacific Oceans. Its movements over the land give one a good idea as to *how fins developed* into terrestrial limbs. Fig. 104 shows the flying-fish with its large pectoral fins which sustain it in gliding flights of 200 yards through the air.

These wonderful links help us to understand how land animals were evolved from fishes. So far, the vertebrates we have discussed are all water animals; we must now "land our fish" and watch his development into a dry-land creature. How many people would care to classify the objects in Fig. 105 at first sight? They look as if they represented only one group, but they belong to three distinct orders. The bottom one is a fish—the electric eel. The middle one is an Amphibian (*Cæcilia lumbricoidea*), and belongs to the same order as frogs and toads. The top one is a reptile known as Amphisbæna, so called because it can crawl either end first.

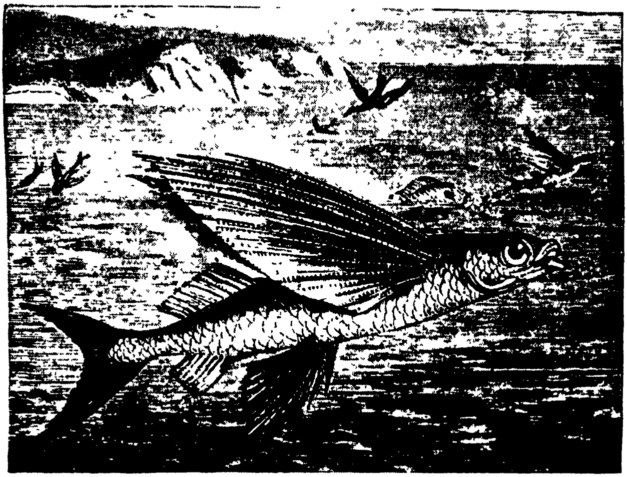


FIG. 104.—Flying-fish.

The extraordinary variety shown in the class of fishes is most striking, and, once we appreciate the fact of natural selection incessantly working on countless variations always present, we need not wonder that of these some were in the direction of life on land. But this mighty advance took a long time, for only by a series of multitudinous small structural changes was it possible for a water-dwelling, water-breathing animal to turn into a land-dwelling and air-breathing one. The connecting links between the true fishes and purely terrestrial vertebrates are the *Dipnoi* or "double-breathers" and the *Amphibia* or "double-livers," both of which are capable of living in water and on land at some stage of their existence. The Amphibians have had their day; they once reigned throughout the swampy lands, but now are represented by only about 1,000 species as compared with 250,000 species of Insects, 3,000 species of Fishes, and 10,000 species of Birds. There is no doubt that Amphibians have sprung from fish-like ancestors, and in turn have given rise to Reptiles; they hold a position between the two, and are real connecting-links.

FIG. 105.—Reptile, Amphibian, and Fish.

We have seen that some fishes possess a lung or lungs, or other accessory breathing organs that enable them to live out of water for a time, and it is among them, and especially among the Dipnoi and Crossopterygii, that we must seek the origin of Amphibians. The Siren, or mud-eel, possesses no hind limbs and it retains its gills even after its larval or tadpole stage has been passed; it *seems* far nearer the fishes than is a toad, yet is a true Amphibian.

The newt, or eft (Fig. 106), of our ponds and ditches, though a modern animal, resembles the Dipnoi in its

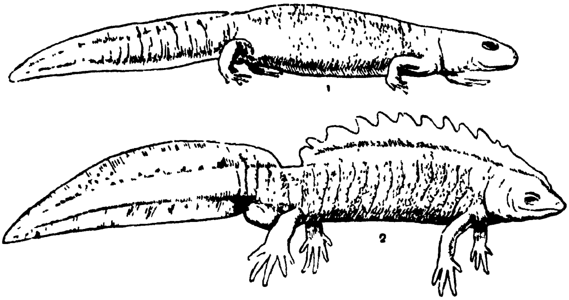


FIG. 106.—Warty Eft: (1) female; (2) male.

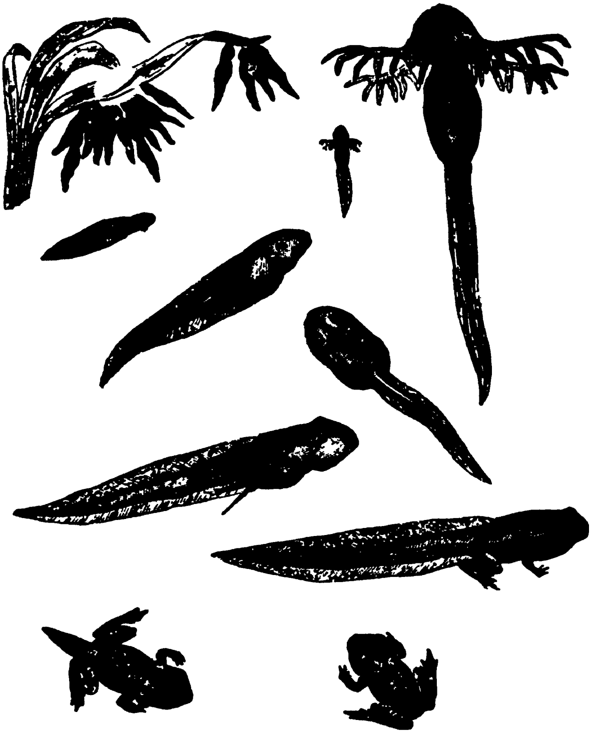


FIG. 107.—The Growth of the Frog.

arrangement for breathing. Such creatures as the Siren and eft help us to form a notion of the appearance of the earlier Amphibians.

The frog (Fig. 107) is a modern and specialized Amphibian. From the " eggs " of the " frog-spawn " tiny free-swimming larvæ or tadpoles emerge. For a day or so they cling, by means of an adhesive disc, to the leaves and stalks of water-plants; then, using their tails, they begin to swim about, breathing in the oxygen dissolved in the water through their gills. Such is the fish-stage in this Amphibian's ontogenetical evolution. After a time the tail becomes absorbed, hind-limbs appear and, a little later, the fore-limbs. Gills now cease and lungs commence to function, and presently the young frog crawls out of the water and, from being a Fish, becomes an Amphibian.

We come next to Reptiles, a word meaning " crawling things." They have scaly skins, and most of them very short legs; the class includes crocodiles, tortoises, lizards, and snakes. As can be judged from the numerous fossils found all over the world, the reptiles increased and multiplied to an amazing degree, until, finally, they had the land practically to themselves. We should always bear in mind that the vast majority of orders of reptiles is now extinct.

It is probable that, on the one hand, reptiles *evolved from* one or other of the " roof-headed " Amphibians (*Stegocephala*) in the lower Carboniferous period, and that, on the other hand, some of them *evolved into* the Theromorphan and Diapsid reptiles from which, respectively, sprang the primitive mammals and birds. Mammals sprang from the *Theromorpha* (" beast-shaped ") in early Permian days, while in the upper Permian, or possibly later in the Triassic, the birds branched off from a group of small lizard-like reptiles, which, like the Dinosaurs, had adopted a bipedal locomotion, especially when running, in which action they probably helped themselves along by a backward thrust of their upper limbs as does the ostrich to-day. Still later, possibly for purposes of safety, they took to climbing trees and so further developed the upper limbs in the direction of wings by practising " gliding leaps " from tree to tree, as do our present-day " flying squirrels " and " flying frogs." To us, reptiles are a very interesting class, for if mammals came through them, so also did man.

The Proreptilia class are, as their name "before-the-reptiles-proper" indicates, the lowest known forms. They link the Amphibia below with the higher Reptiles above; indeed, for a time they were mistaken for the roof-headed Amphibia with whose remains they lay amid the Permian rocks. The Prosaurians constituted a slightly higher stage, though they still retained many of the primitive features of their amphibian forbears. They were, for the most part, small newt-like animals—again of the Permian period—with five fingers and toes.

Only one species of these Prosaurians (*Sphenodon punctatus*) exists to-day, and that lives in New Zealand in the pride of antiquity. Think what the ancestors of this remarkably conservative creature must have seen; they witnessed the headlong downfall of the mighty reptile rulers which had conquered air, land, and water, the advent of egg-laying mammals, and the revolutionary advance of the warm-blooded, viviparous, milk-giving mammals. They saw the several stages wherein certain of their cold-blooded, scale-covered, sluggish, toothed cousins developed into feverishly-active, hot-blooded creatures with beaked jaws and feathered skins. They saw, too, the drab earth become covered with gay-

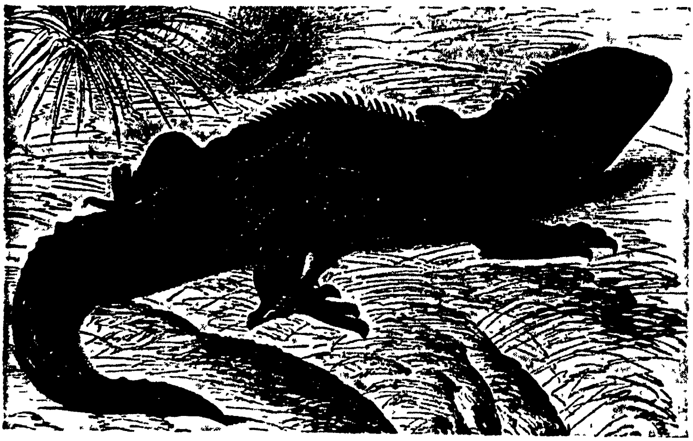
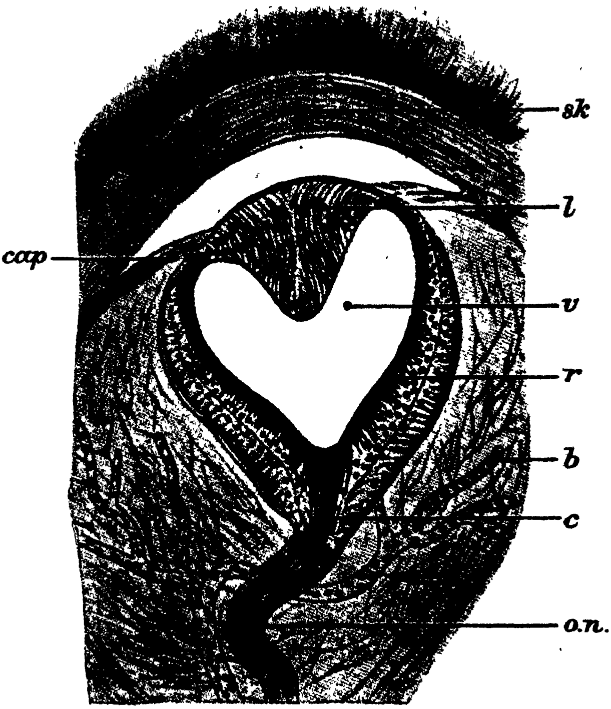


Fig. 108.—Sphenodon.

coloured flowers; and, finally, geologically speaking but a few years ago, they were witnesses of the transformation of that particularly insurgent mammal, ape-man, into



From Dr. R. Wiedersheim's "Structure of Man" (Macmillan).

FIG. 109.—Section through Pineal Eye of the reptile *Hatteria* or *Sphenodon*.

Sk, skin and tissue covering head; *cap*, capsule of eye; *l*, lens; *v*, vitreous chamber filled with clear fluid; *r*, retina; *b*, blood-vessels; *c*, cells linking up retina with optic nerve (*o.n.*).

man, and, in the latter, of the subordination of muscle to brain!

The *Sphenodon* (Fig. 108), also known as the *Hatteria* or *Tuatara*, the "Spiny one," as the Maoris call it, is not a lizard, but a very generalized type of primitive reptile, the last living witness of the long bygone Prosaurians. It is said to be incorrigibly lazy, sleeping most of the day in the water, below the surface of which it can remain for hours without breathing, coming out in the cooler hours to feed on worms and insects. Owing to its having been mercilessly hunted by the Maoris, this "living fossil" has become so rare that steps have had to be taken by the New Zealand Government to prevent its following the example of the Dodo of Mauritius, which was exterminated in 1681 by the Dutch immigrants and their pigs. The interesting evolutionary point about Hatteria is that it has retained, in a probably slightly functional form, the pineal eye at the top of its head, with retina, lens, and optic nerve all present (see Fig. 109). Remains

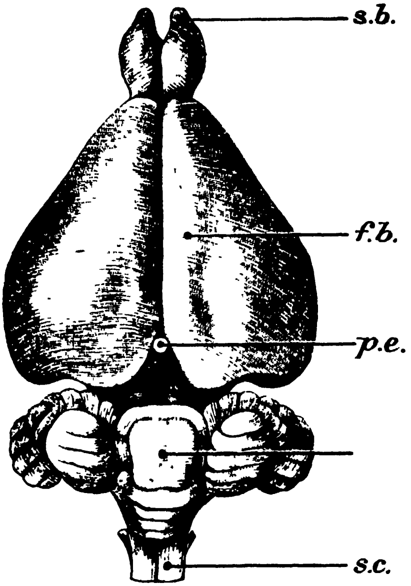
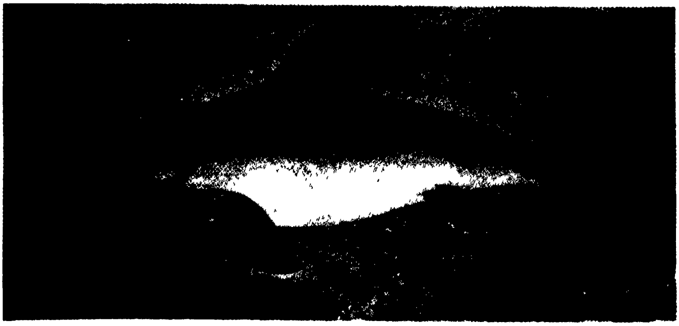


FIG. 110.—Upper surface of Rabbit's Brain, showing the remains of the Pineal Eye.

In front is the relatively large smell-brain (*s.b.*) behind which is the smooth fore-brain (*f.b.*). The remains of the pineal eye (*p.e.*) can be seen below and between the hinder borders of the fore-brain. The little brain or cerebellum (*c.*) and spinal cord (*s.c.*) are also shown.



From Sir Ray Lankester's "Extinct Animals" (Constable).

FIG. 111.—Drawing to show the probable appearance of an Ichthyosaurus swimming beneath the surface of the water.

of this "third eye" (as it is wrongly called) are present in lampreys, frogs, and lizards, and can sometimes be seen in the frog on the top of the head between the normal lateral eyes as the so-called Stieda's organ. In the extinct Amphibia and reptiles of the Palæo- and Meso-zoic periods, this median eye, or rather pair of eyes, was much better developed. Recent embryological research has demonstrated that the remaining pineal eye in *Sphenodon* is the *left* eye of the ancestral pair, while that in the lamprey is the right one. Birds and mammals also possess vestiges of this extra median pair of eyes. In man this vestige, the pineal organ, was thought by Descartes to be the seat of the soul, owing to its lofty and symmetrical position. In ourselves and mammals generally the *present-day function* of the organ is to manufacture and pour out into the blood-stream certain chemical compounds which exert a powerful influence on the development and growth of the primary and secondary sexual organs.[1]

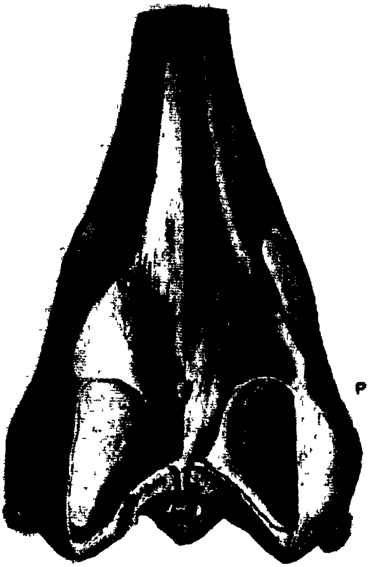
The Theromorphan reptiles include, among others, the Pariasaurs (Fig. 63) and Theriodonts, or reptiles with mammal-like teeth (Figs. 64 and 65). As already stated, it was probably through the Theromorphs that the genealogical line of the Mammals passed.

---

[1] The main function of the pineal organ is to retard the action of the *hormones* or *endocrines* of other organs, e.g., *pituitrin*, *thyroxin*, *insulin*, *oestrin*,—and the *testicular hormone*, of the pituitary, thyroid, pancreas, ovary, and testis respectively. The pineal organ is thus a super-endocrine organ that checks over-activity on the part of any member of the endocrine system.

All the reptiles of this sub-class are now extinct; the earliest known occur in the lower red sandstone of Thuringia and Bohemia, and in the middle Permian of Russia.

The Plesiosaurs (near-reptiles), Dolichosaurs (long-reptiles), Ichthyosaurs (fish-shaped-reptiles) (Figs. 111, 112), Pterosaurs (winged-reptiles) (Figs. 68, 113, 114), and Mosasaurs (Meuse-reptiles), all flourished in the Jurassic-Cretaceous ages and then died out. Ichthyosaurus provides a good instance of zigzag evolution; originally a fish, it took to dry land as an Amphibian, became a land reptile, returned to the sea and became a water reptile. Finally, it so adapted



From Sir Ray Lankester's "Extinct Animals" (Constable).

FIG. 112.—Photograph of the upper surface of the Skull of an Ichthyosaurus.

On a level with the letter P, in the middle of the skull, is seen an oval pit, the "parietal foramen," in which was lodged the "third" eye.

itself to aquatic life that it assumed a fish-like form. But Evolution never forces back a type it has brought forth into the type from which it has come; a "lung," for example, once evolved never reverts to a "swim-bladder," nor a "hand" to a "fin." The Ichthyosaurus had to keep up lung-breathing, and under the skin of its fore-paddles, despite their fin-like look, the old terrestrial hand still persisted, though the fingers in certain types showed an increase from the generalized pentadactyle pattern to six or even seven digits. Some Ichthyosaurs were but a few inches long; in others the *skull alone* measured six feet. Some laid eggs, coming ashore to the sands for that purpose, but others became so specialized to aquatic life that they brought forth their young in mid-ocean as do whales and dolphins. This has been proved by the finding of certain fossil skeletons inside which were the more or less perfect fossil bones (thus showing they had not been swallowed) of unborn young. Finally, some of these sea reptiles possessed a median pair of eyes at the top of the head in addition to the pair of lateral eyes (Fig. 112). Few people would see any connection at first sight between a snake and a bird. But if we compare certain of the bird-like reptiles with a modern bird stripped of its feathers, we see very distinct resemblances. Reptiles are scaly animals, while birds are feathered ones. Phylogenetically feathers are really scales that have become elongated, softened and frayed out; ontogenetically, both feathers and scales are

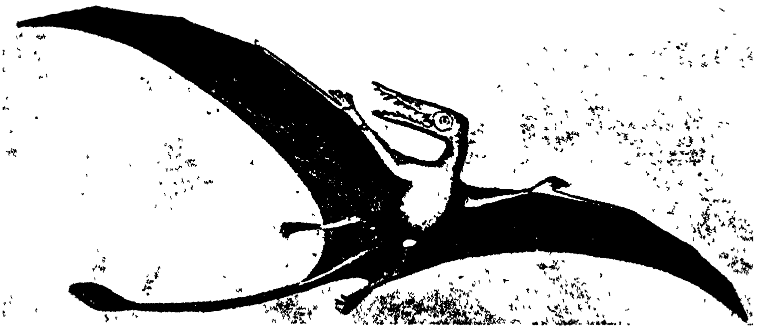


FIG. 113.—Ramphorhyncus.

specialized developments of the outer horny layer of the skin.

Ramphorhyncus (Fig. 113) was a reptile that had membranous wings and flew like a bird. This Pterosaur or

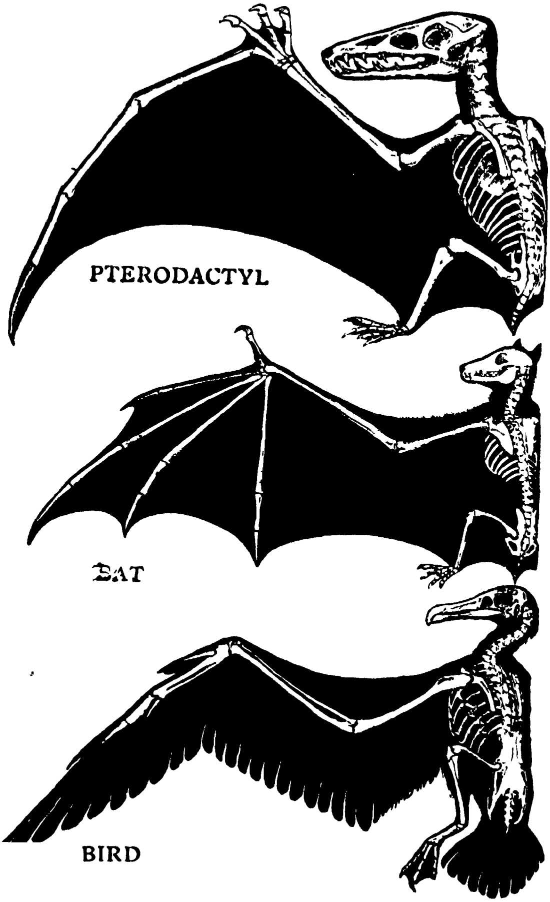


FIG. 114.—Wings of Reptile, Mammal, and Bird.

Pterodactyl flourished in the Jurassic-Cretaceous times and its remains have been found in Bavaria. In Fig. 114 the one at the top is a *reptile*, a wing-fingered Pterodactyl. Observe that it is the finger that corresponds

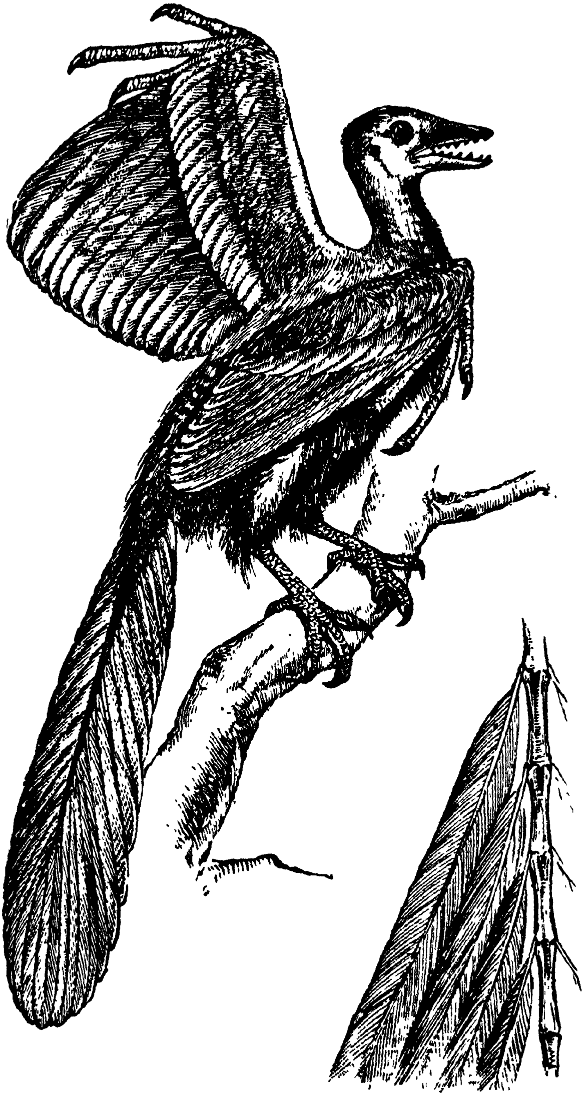


Fig. 115.—Archæopteryx. Below, a part of the reptilian tail.

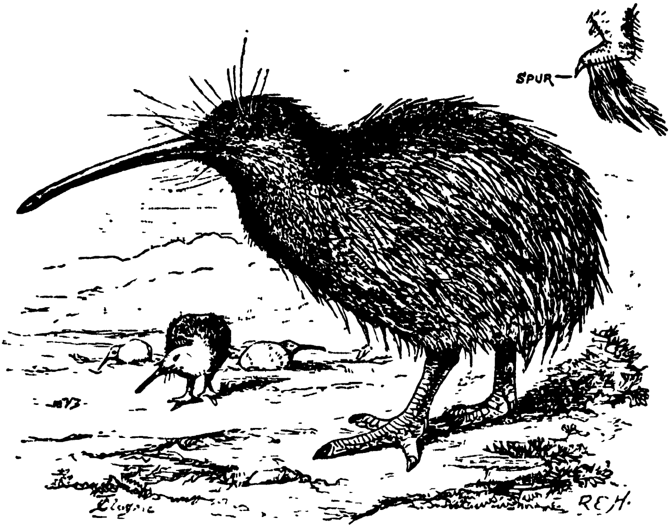


FIG. 116.—Apteryx. Above, the index "finger."

to our fifth that is greatly prolonged to support the wing. The bones, like those of a bird, are hollow and filled with air. In size these creatures varied from a robin to an eagle. The central animal of the figure is a *mammal*, a bat, while the lowest is a *bird*. The picture exemplifies in three totally different classes of animals (reptiles, mammals, birds) organs (arms) that possess both an *analogous*, that is, an adaptive, and a *homologous*, that is, an anatomical resemblance. Such resemblances form what is known as *Convergence* in evolution in conformity with some common habit—in this case flying.

Fig. 115 shows the Archæopteryx ("the old bird")—well named, for it is indeed the oldest known member of the feathered tribe, its remains being found in the same rocks as the flying reptiles. It was rather smaller than a crow, and united some of the characters of reptiles with those of a true bird; for instance, it had four well-developed toes, three of its fingers ended in claws and were free, it had teeth, and a reptilian tail in which each vertebra carried a pair of quill feathers. It was, in fact, a link in the evolutionary chain, a creature that had been reptile but was not yet bird—a true reptile-bird. Despite their many extraordinary resemblances (for instance, the nostrils, the neck vertebræ, shoulder-blades, fibulæ, the pre-orbital foramina, the brain, hollow bones, warm blood, etc.) to the birds, the Pterosaurs were true reptiles, they were not even reptile-birds. They, the mammals, the reptile-birds, and birds, had been shunted off the main reptile line along three distinct and separate branch lines.

There is a weird bird of New Zealand known as the Apteryx or Kiwi (Fig. 116) which has entirely lost the power of flight. So rudimentary have its wings become in consequence of disuse that they must be searched for amid the long hair-like feathers. It passes the day in a burrow, coming out at night to probe the ground with its long sensitive beak and "smell out" earth-worms by means of its nostrils, which, unlike those of other birds, are situated at the very tip of the upper beak.

Kiwis are the smallest members of a widespread and big-bodied family, to which the ostrich and emu belong; in historical times New Zealand had the largest specimen of this family, the Moa (Dinornis), which had thigh-bones longer and thicker than those of a horse.

As we are naturally more interested in mammals, these few examples of birds must suffice to show that the most unlike animals have come, by different lines, from the same ancestors. So, when you see a cat stalking a sparrow, remember that both animals, despite their very different habits and appearances, have come through reptiles from the same group of roof-headed Amphibians. You cannot cross laterally from one side line or branch of a genealogical tree to another, but if you trace all the side lines or branches far enough back, you will find they converge to meet in great centres, which represent the common ancestors.

CHAPTER FIVE: MONKEYS AND MAN

IN this chapter we trace the evolution of mammals; for us the most important group of all, since it is the one to which we belong.

The better to understand the method of evolution it will be well to bear in mind three general principles:

(1) Animals that have developed along side lines have no participation in the evolution of man. Birds, for example, in no way figure in man's ancestral pedigree, for they are in a side-branch that left the main reptilian stem at one point, while mammals and man are in another side-branch that left the same stem at a different point. Modern birds, modern reptiles, modern mammals and man are the terminal leaves, so to speak, of twigs and branches that have diverged from a common pro-reptilian stem or stock.

(2) Over-specialization and over-growth are potent causes of extinction.

(3) The larger and more highly-specialized animals have evolved from smaller, simpler, and more generalized types.

Many of these earlier and simpler forms have become extinct, because in the struggle for life they were destroyed by the later, more specialized, animals. Yet here and there, in out-of-the-way corners of the earth, a few have survived; and by means of these and the fossil ancestors found in the rocks we are able to trace the evolution of many families of animals with remarkable clearness.

Fig. 117 shows a familiar mammal. Without exception all animals the females of which suckle their young are called mammals (*mammæ*, breasts). There are many other distinguishing marks, but this one is sufficient.

Viewed externally Fish are distinguished by their fins, Reptiles by their dry, horny scales, Birds by their feathers, and Mammals by their hair. We must remember, however, that such very unlike structures as scales, feathers, hair, wool, nails, hoofs, and claws are in origin identical, being but modifications of skin-cells. Scales are still found on armadillos, as well as on the legs of birds; and practically all the fingers and toes of mammals have either nails or claws, which are modifications of the scales of reptiles. The dappled markings on some horses are probably aftermaths of the scales of far-back ancestors. The

FIG. 117.—A Sow and her Young.

present writer has frequently observed polygonal-shaped patterns on the human skin (especially in cold weather) that are probably explainable in similar terms.

Mammals are divided into three classes: (1) The primitive mammals or Prototheria; (2) the modified mammals or Metatheria; and (3) the perfect mammals or Eutheria. Fig. 118 shows a mammal and a reptile. It would puzzle anyone not conversant with biology to imagine how the cow could be related to the lizard. Note that Evolution does not teach that the cow *came from* the lizard, but that all existing mammals, including of course, the cow, and all existing reptiles, including the lizard, have come *through* a particular *group* of ancient reptiles, the several members of which were descendants of a common proreptilian ancestor. We should commence our study of

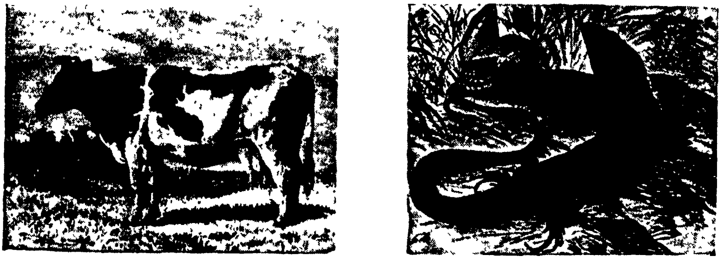


FIG. 118.—Cow and Lizard.

the mammals, not with a highly-specialized type like the cow, but with a primitive one such as the duck-billed platypus (Ornithorhynchus) (Fig. 119). This is, without doubt, one of the most curious animals in the world; indeed, when first brought to this country it was believed to be a deliberate fraud, like the mermaids which used to be made by neatly stitching together the forepart of a monkey and the tail of a salmon! The Platypus, or duck-mole, whose home is in Australia and Tasmania, is a representative of one of the two families of primitive mammals, the other family containing the Spiny Ant-eater of Australia; both families, the *Echidnidæ* and *Ornithorhynchidæ*, forming the Order *Monotremata*. The Platypus is a little larger than our mole and is covered with a dense, dark brown fur; the limbs are short and five-digited, all the fingers and toes being webbed, but, as you can see in the picture, the webbing on the fingers extends considerably beyond the tips of the claws, as in seals, but leaves the claw-tips free in the case of the feet. The beak is broad and flat, and suggests that of a duck; it is not, however, covered with horn, but with a soft, sensitive, naked skin. The brain is smooth, and there is no *corpus callosum*, or band of nervous matter uniting the two hemispheres of the cerebrum as in the higher mammals. It has real teeth in the earlier part of its life, but as these get worn down they are shed just as are milk teeth. As might be expected, these teeth show a general resemblance to those of certain

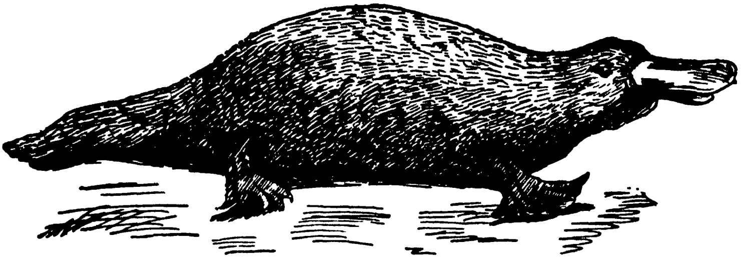


FIG. 119.—Duck-billed Platypus, or Duck-mole.

fossil mammal-like reptiles. The duck-mole is aquatic, making a burrow in the bank of a stream; it lives on grubs, worms, snails, but with a special *penchant* for fresh-water mussels. In common with reptiles and birds, it lays large-yolked eggs, which, however, are covered with a tough membrane and are incubated by the mother in a nest within the burrow. She has no teat for the young to suck, the milk simply soaking the hair around her milk-glands, whence it is licked off by the little ones.

Of the many other points which indicate the intermediate position of the Monotremata between the reptiles and mammals, space will only permit of allusion to one. The blood of a higher mammal is relatively " hot," and its temperature is more or less constant—that is, it is not unduly influenced by the surrounding temperature. The blood of a reptile is relatively " cold," with, however, a wide range of temperature-variation that is directly related to changing temperature of the environment. If the monotrematous mammals, Echidna and Platypus, are really connecting links between the lower reptiles and the higher mammals we should expect their blood to be " neither hot nor cold," but lukewarm, and we should further expect it to have a fairly wide range of temperature-variation. Now the temperature of these animals is actually intermediate between that of reptiles and the higher mammals, while the range of temperature-variation is very liberal, as much as 13 degrees Centigrade in the case of Echidna. Thus the very blood heat of these " Monotremes absurd, that lay eggs like a bird," reveals secrets of evolution, for it informs us, *inter alia*, that the weird families comprised by the *Echidnidæ* and *Ornithorhynchidæ* are feeling their way, so to speak, from the *poikilothermal* reptiles to the *homœothermal* mammals.[1]

Let us proceed to the next group of mammals, the marsupials (*marsupium*, a pouch). Fig. 120 shows the Rock Wallaby, which is of the same sub-family as the kangaroos. For the most part these pouched animals are found in Australia, though some kinds exist in the islands to the north of it. Millions of years ago in the Mesozoic epoch they occurred in Europe and N. America in great numbers, a fact that explains the existence of a subdivision in S. America. The marsupial presents us with another "link-animal"; for, especially as regards gestation, its position is the mean of that of the Monotremata or Prototheria (first beasts) which bring forth their "young" in the utterly undeveloped state represented by an egg, and the higher mammals or Eutheria (perfect beasts, such as man!), inside the females of which the young complete practically the whole of their development. In the kangaroo the young one is born as a tiny, naked embryo about the size of the little finger, and in so helpless and imperfect a condition that the mother has to pick it up with her lips and place it to a teat inside her pouch. The little one is provided with a special "larval organ" in the shape of a clasping mouth, and by this it clings pertinaciously to the teat though quite unable even to feed itself, its nourishment being effected by the mother squeezing her milk glands by special muscles and so forcing the fluid down its throat—in very much the same way that the mother whale feeds her young. The "egg" of the kangaroo, which, as we have seen, is not extruded as in the Monotremata but is retained within the female, is very small—a point in keeping with the type of ova in the typically higher Eutherian mammals. But at its first division the kangaroo egg divides incompletely, a feature reminiscent of the large-yolked eggs of reptiles.

---

[1] *Poikilos*, various; *homoios*, like; *therme*, heat.

Fig. 120.—Rock Wallaby.

In many points the Metatheria are an advance upon the more primitive monotremes: they have developed a clavicle, possess teats, their cerebral hemispheres are furrowed and connected up by a rudimentary *corpus* *callosum*. Though in their general structure they hold a position midway between the primitive mammals and the mammals proper, yet it is not considered that any marsupials of a type such as those existent to-day are in the direct line of evolution of the higher mammals. Marsupials are a distinct side line, but with numerous and widespread ancestors, and as regards the present families we cannot say more than that they help us to understand some of the gradual stages through which the higher and more perfect mammals probably passed. All that is known with any degree of certainty concerning the origin of mammals as a whole is that somewhere about the time of the Permian-Triassic age a group of mammal-like reptiles branched off from the main reptilian stem and then broke up into further branches representing animals with quasi-mammal characteristics. These branches were—(1) Cynodonts, (2) Protodonts, (3) Triconodonts, (4) Multituberculata, (5) Trituberculata, (6) Archaic Monotremata, (7) Archaic Marsupialia, and (8) Archaic Placentalia or true Mammalia, the females of which nourish their unborn young through the mediation of a placenta.

It is in the Triassic rocks we first meet with the remains of undoubted mammals. When they did appear on the earth it was in a " tentative and hesitating way," for they were small and surrounded by huge, fierce carnivorous reptiles. These early and primitive mammals lingered to the Eocene period. In the bed of rocks next above the Trias, that is, the Jurassic, three groups of small animals have been found. One of these groups contains the *Primitive Insect Feeders*, among which *Amphitherium prevostii* found in Stonesfield slate, near Oxford, was a creature about the size of a rat. Our modern Insectivora can be traced back to shrew-like creatures, our Carnivora to the Creodonta (flesh-toothed), and our Ungulata to a group represented by Phenacodus, all three types belonging to the Eocene. The earlier members of the higher mammal stock, to which we shall return in due course, were small creatures with long slender tails, five-toed hands and feet, forty-four teeth, and a small head and brain.

Before we deal with our proximate ancestors we may as well dispose of two remarkable groups of mammals.

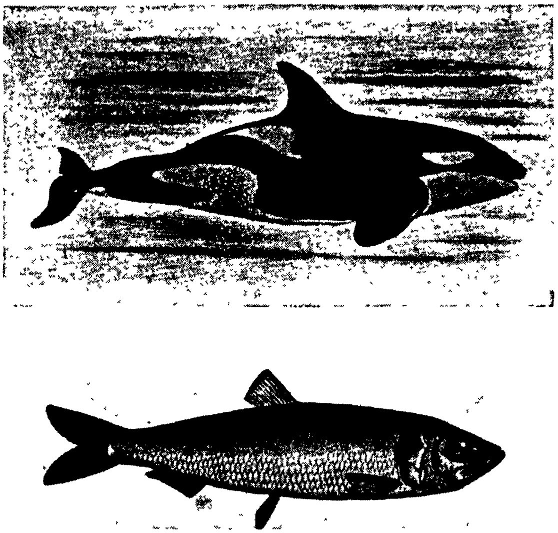


FIG. 121.—Whale and Herring.

In Fig. 121 the two animals look much alike, but the top one is a mammal, the killer-whale, while the bottom one is a fish, the herring. There are still people who do not know that the whale is a mammal, with warm blood, bringing forth its young alive and suckling them by mammary glands. The teats of the mother are towards

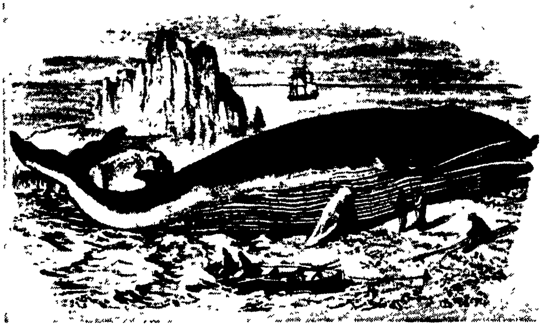


FIG. 122.—Rorqual.

the tail-end of the body, and she holds her young up by a sort of flipper, while she squeezes the milk down its throat. There are many families in the class of whales. Perhaps the best known is the rorqual (Fig. 122). You can see what a gigantic beast this is. It has been known to measure over 100 feet in length, and to weigh several tons. Most people are familiar with whale-bone, which is not bone at all but a horny product of the lining of the mouth, where it is found in huge transverse ridges. This stuff is worth over £2,000 a ton; and, as a single whale may yield several tons, we can easily understand why people take up the dangerous pursuit of whaling. The larger kinds of whales are so heavy that they cannot live on land, for the great weight of their chest-walls prevents the movements requisite to respiration. The position of the whale among mammals has for long been a moot point with biologists, but recently a bio-chemical examination of this animal's blood has shown that it is closely related to the swine family.

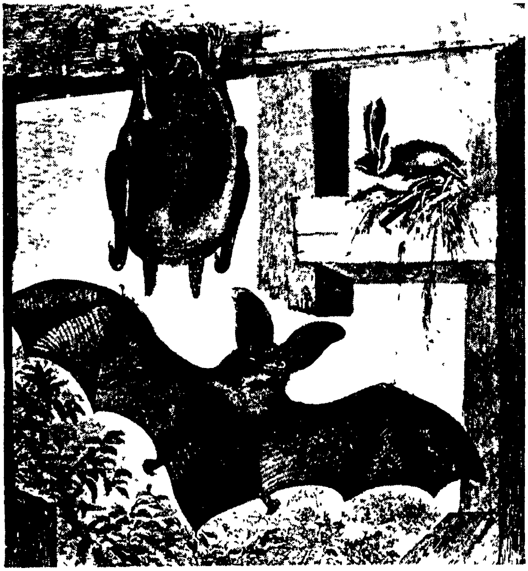


Fig. 123.—A Flying Mammal—the Bat.

Fig. 123 shows a bat hanging—as they always do when asleep—curled upside down, while below we see it with its membranous wings extended. There are many families found all over the world, and one family, the Vespertilionidæ, contains over 190 species. Bats probably constitute a line of mammals that branched off from the main stem in late Cretaceous and early Eocene days.

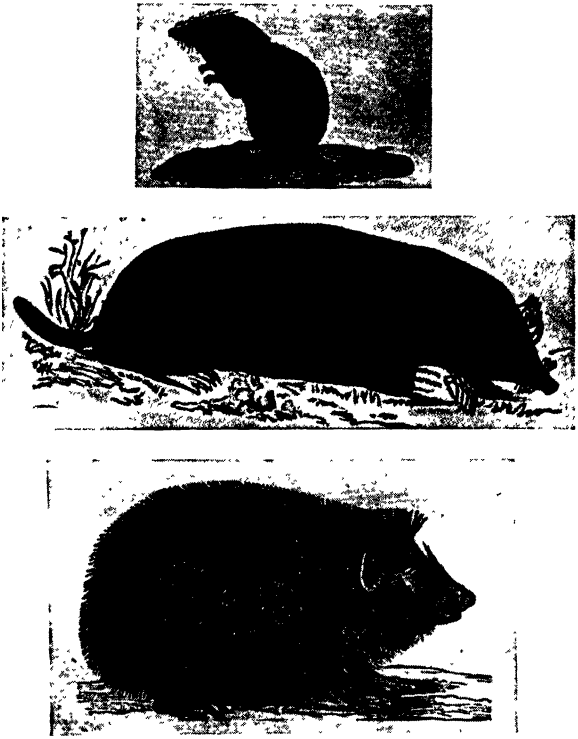


Fig. 124.—A Group of Insect-eaters.

The Insectivora, so called because they feed on insects, are in the main line of the mammals. Fig. 124 shows three common but interesting types. The small animal at the top is the shrew (*Sorex*), often called a shrew-mouse, although it is not really a mouse, being more akin to the mole. Shrews are a very old family, and very widely spread; one of them, *Sorex minutus*, is the smallest British mammal. The larger animal, in the middle, is the common mole (*Talpa Europæa*). It is found only in the Old World, though there are mole-like creatures in America. The bottom animal is the hedgehog (*Erinaceus*). It not only eats insects and slugs, but also chickens, young game birds, and vipers. These three creatures are among the most interesting of English animals because of their enormous antiquity, and because they give us a hint of the kind of small ancestral mammals from which all modern ones, including mankind, have sprung.

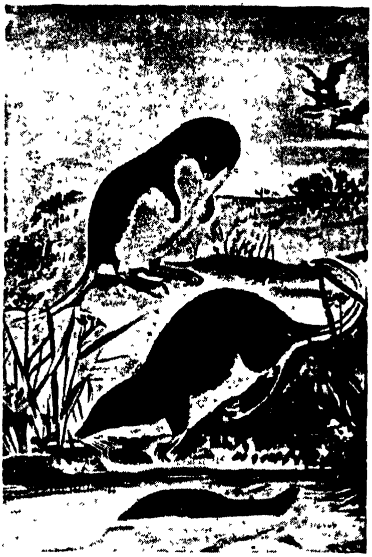


FIG. 125.—A Group of Water-Shrews.

Fig. 125 shows water-shrews, which are larger than the common English shrews. They are not "true shrews," but belong to a family connecting these with the moles.

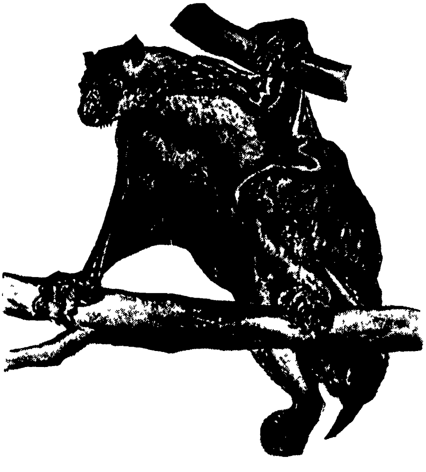


FIG. 126.—Weasel-Ape.

The remarkable animal shown in Fig. 126 has been classed now as a lemur and again as a bat; and yet again it has been placed all by itself in a special order of mammals. Dr. Beddard says: "It is better to regard it as an aberrant Insectivore—so different indeed from other forms that it requires a special sub-order for its reception." It is a larger animal than any other Insectivore, being about the size of a cat. *Galeopithecus volans*, as this creature is called, inhabits the Oriental region. It has a remarkable fold of skin, the patagium, which extends from the neck to the fore-limb, and thence to the hind-limb and tail, by means of which it is able to fly. This membranous fold is midway between that of the flying-squirrel and the bat. In this and other ways Galeopithecus is a real connecting-link—a sort of composite animal holding affinities with the bats, flying-squirrels and lemurs.

Shipley and MacBride say: " The most interesting circumstance about the Insectivors is the fact that when, by means of fossils, we trace back the higher groups of mammals, they *all* seem to merge imperceptibly into Insectivors—*i.e.* the *primitive* insect-eaters.

" There is really good ground for supposing that the living Insectivors, though modified in special details, nevertheless represent, so far as their general organization is concerned, the earliest type of Eutheria which appeared on the globe. From these original Insectivors advance seems to have taken place along five lines:—

" I. Some Insectivors took to attacking larger prey, including their own less fortunate relations, and gradually developed into the Carnivora, or flesh-eating mammals. These are tigers, cats, dogs, wolves, etc.

" II. Some became vegetable feeders, and gave rise to the great group of hoofed animals, relying either on their swiftness, or size, or strength for defence. These are horses, cows, elephants, etc.

" III. Some took to burrowing, and developed into gnawers or Rodents, relying chiefly on their holes for safety. These are rabbits, rats, mice, squirrels, etc.

" IV. Some took to the air, the fore-limb becoming changed into a wing. These are the bats.

" V. The remainder took to escaping into trees when hard pressed, and eventually gave rise to the great group of the Primates, which includes monkeys and man."

Leaving the first four groups as side lines of evolution, we will devote our attention to the Order Primates, a name meaning " first " or " highest." All zoologists now agree that lemurs, monkeys, and man must be classed in the same Order, a fact which in itself is a remarkable testimony to the truth of the evolution of man.

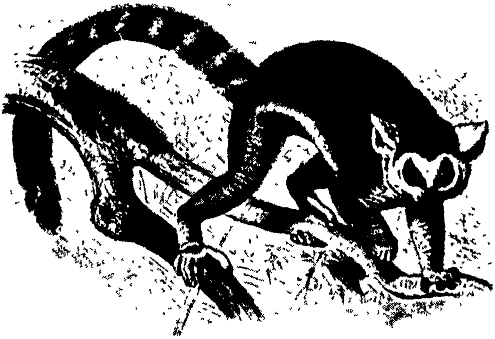


FIG. 127.—Ring-tailed Lemur.

The Primates are divided into two sub-orders :—

(1) Lemuroidea, or lemur-like animals.
(2) Anthropoidea, or man-like animals.

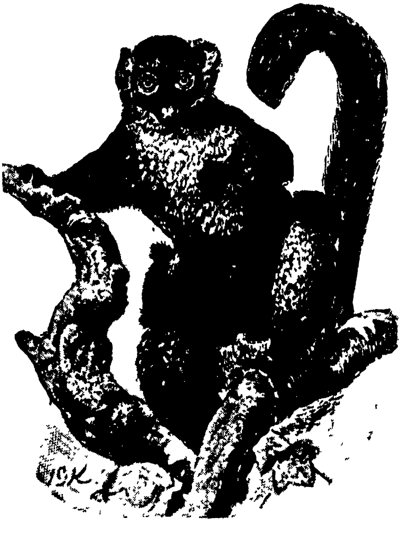


FIG. 128.—Black Lemur.

There are three families and four sub-families of lemurs. In Latin, *lemures* means the ghosts or spirits of the dead, and as these animals come out mostly in the night and are silent, mysterious, and ghost-like in their movements, Linnæus named them lemurs. The Indris, found only in Madagascar, has much larger legs than arms; the ears are short, the tail varies in length, the thumb is but slightly opposable, and the toes are webbed. When it walks on the ground it does so on its hind limbs, holding its arms above the head. The ring-tailed lemur (Fig. 127) has flat, human-like nails on all its fingers except the forefinger.

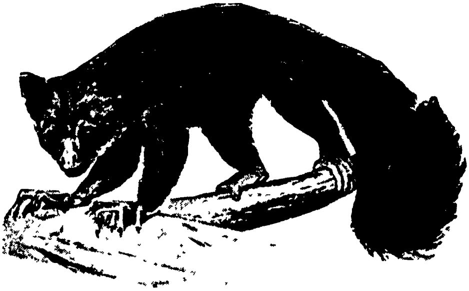
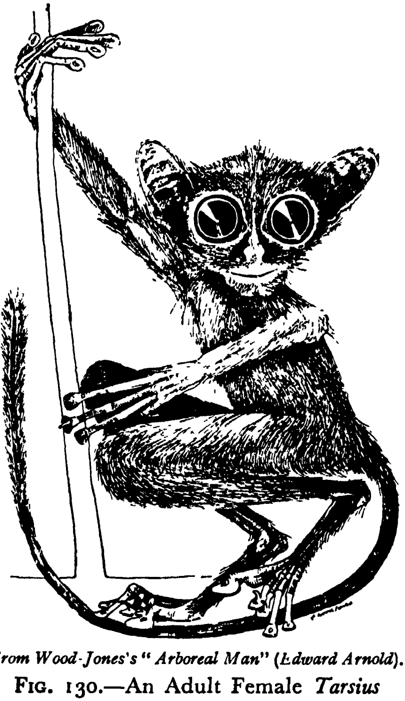


Fig. 129.—Aye-Aye.

Fig. 128 shows a mother lemur with her little one lying across her belly. The young one is often carried in this way by the mother; its tail passes round her back, and then round its own neck. It has been suggested that this instinct came from ancestors which used to carry their young in a pouch, after the fashion of marsupials (Fig. 120).

The Lemuroids are the most ancient of the Primates. The Aye-aye (Fig. 129) and *Tarsius spectrum* (Fig 130) are the living relics of far-back ancestors whose fossils have been found



From Wood-Jones's "Arboreal Man" (Edward Arnold).

Fig. 130.—An Adult Female *Tarsius spectrum.*

in the Eocene of N. America and Europe. Professor Wood-Jones believes that Tarsius, the quaint little, wide-eyed, nocturnal tree-lemuroid of Java, Borneo, the Philippines and adjacent islands, is a nearer relation of man than is the ape; that is, that man is in the direct line with the Eocene *tarsioids*. Sir Arthur Keith's, and probably the more prevalent view, is that man *and* ape evolved from a common tarsioid stock which, commencing in the Eocene period, gave off a series of branches in the following order: Lemurs, Monkeys of the New World, Monkeys of the Old World, small Anthropoid Apes, large Anthropoid Apes, Pithecanthropus, Peking Man, Neanderthaloids, Piltdown and Rhodesian Man, and, finally, modern races of men. Yet another view, which would appear to have received the support of Professor Elliot Smith, is that in the upper Cretaceous primitive mammals of the jumping-shrew type became the tree-climbing, insect-feeding shrews from which arose the Tarsiodea. From these evolved, in the Eocene, first the New World, and later the Old World, Monkeys. In the Oligocene there arose from the latter the ancestral representatives of the Anthropoid Apes. These, continuing their evolution through the Miocene and all the while throwing off several side-branches, gave off in the late Pliocene and subsequent periods a series of branches representing the extinct and surviving races of man (see Fig. 12). The Aye-aye (Fig. 129) hails from Madagascar and is a most remarkable animal. Its bushy tail and long incisor teeth are like those of a squirrel. There is one pair of abdominal teats in the female; the third finger is much longer than the others and very thin, while the thumb and big toe have *flat* nails. All the other digits have claws. It is believed to thrust its long middle finger into holes and crevices in trees, and with it to ascertain the presence or otherwise of grubs, and especially the fat larvæ of a certain wood-boring beetle to which it is very partial. Once discovered, the food is extracted with the help of the chisel-shaped teeth. Mr. Bartlett has, however, seen this creature use the slender and specialized digit for " combing out its hair, and for other purposes of the ' toilet '."

The Aye-aye is a mosaic-like animal possessing affinities with many groups. Its incisor teeth are unlike those of lemurs, being more of the rodent type, and there are no canines. There are many superstitions about it among the natives, who so reverence it that they never molest it and bury carefully any specimen found dead. Another species of lemur, the loris, is confined to India and Ceylon. In Fig. 131 it is shown awake and asleep.

The Anthropoidea, or man-like animals, include monkeys, apes, and man. There are 212 species, all contained within two groups—the Platyrrhines (flat-nosed) and the Catarrhines (down- or narrow-nosed).

In Fig. 132 the top monkey on the left and the bottom one on the right are Catarrhines; the other two are Platyrrhines. Observe that in the former the nostrils are narrower and look downwards, whereas in the latter they are broader and turned slightly outwards. The picture also shows the odd arrangement and development of the hair on the head. Flat-nosed monkeys are found only in America, while the down-nosed ones are found only in Europe, Asia, and Africa. The two groups have probably been distinct since the Eocene period, as no fossil remains of intermediate forms between them have yet been discovered. That in the far-distant past two groups of animals should have arisen, and developed

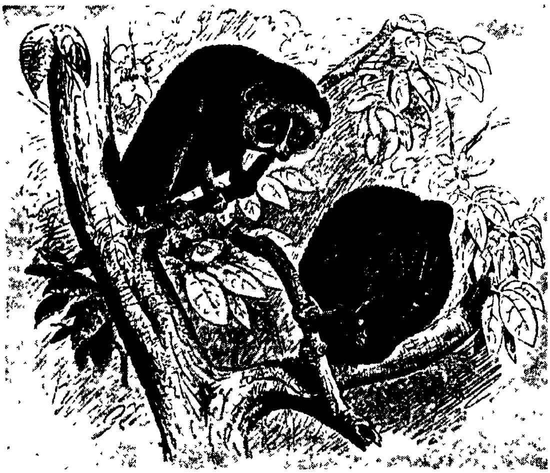


FIG. 131.—Slender Loris.

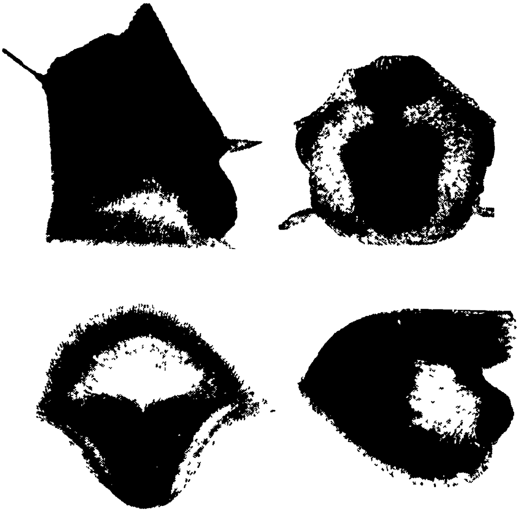


FIG. 132.—Representations of both Families of the Man-like Monkeys.

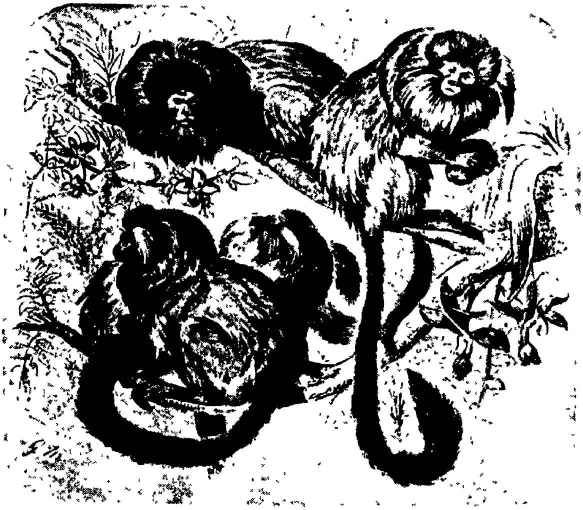


FIG. 133.—A Group of Marmosets

each on its own line never to meet the other again, is an amazing fact.

We will consider the flat-nosed American monkeys first, for they stand near the base of the whole series, and show the connection between lemurs and monkeys. This is another example of the existence of very ancient creatures in South America. *Remember the flat-nosed monkeys are not in the direct line of man's ancestors, but in a side line.* Nevertheless, they are of great interest in that they show some of the common features of the common ancestors. Marmosets, of which there are two genera and some 21 species, belong to the lowest family of monkeys (Fig. 133). In them the fingers and toes are, for the

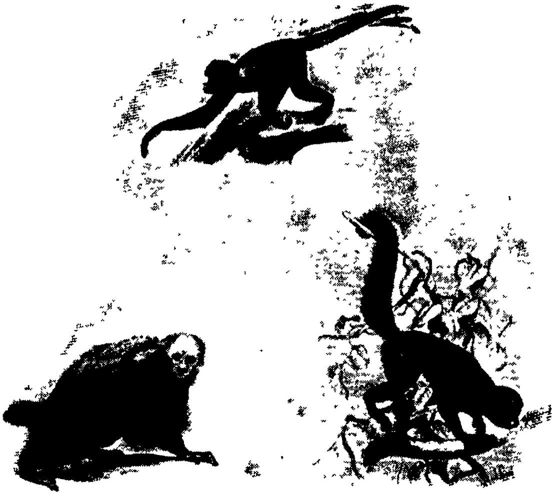


FIG. 134.—A Group of Cebidæ.

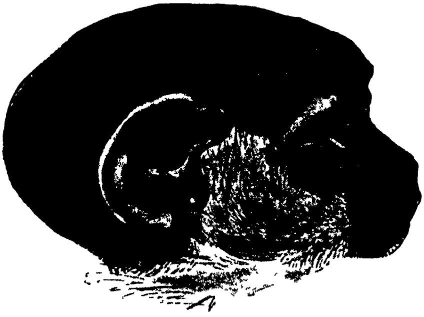


FIG. 135.—Head of Squirrel Monkey.

most part, *clawed*, only the great toe bearing a flat nail, and the tail is ringed—a feature often found in lower mammals but not in higher apes. The Cebidæ or long-tailed monkeys are also peculiar to America. In Fig. 134 the one at the top is the spider-monkey, clinging to a branch with his tail; that at the bottom on the left, with the sad poetic expression, is the red-faced ouakari. The third one is the white-nosed saki.

These monkeys, of which there are five species, have long bushy tails, are bearded, and possess a thumb. One species of saki uses its hand to drink instead of putting its mouth to the water, as the other species do.

The squirrel monkeys (Fig. 135) are small creatures, with long heads and short thumbs. They are remarkable for the size of their heads which, in proportion to their faces, is greater not only than in other monkeys, but than in man himself. Humboldt asserted of one of them that, when vexed, its eyes filled with tears.

Fig. 136 shows six objects. In the top row, beginning from the left, we see the human skull; in the middle the skeleton, and on the right the skull (one of the most human-looking skulls found outside the human family),

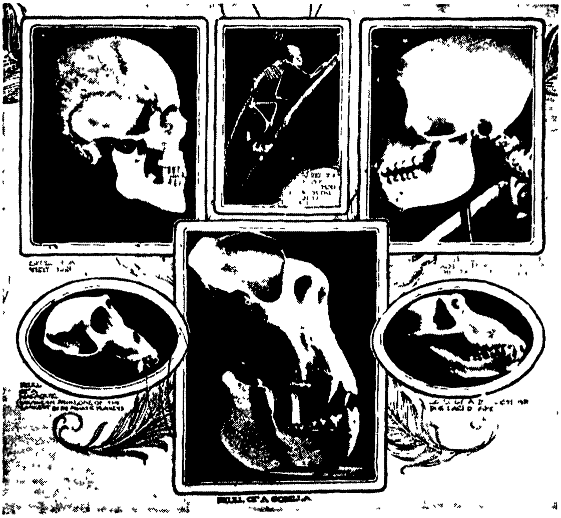


Fig. 136.—Skulls, Monkeys and Man

of the woolly monkey (Lagothrix). In the bottom row the skull of the macaque, one of the largest of the Asiatic monkeys, is shown on the left; that of the gorilla in the middle; and a baboon's on the right. They all look somewhat dog-like because of the projection of their jaws, which becomes yet more marked with increasing age.

The Catarrhines, or down-nosed apes, are of remarkable interest to us, as they are *near blood relatives.* They are divided into three families: (1) The tailed apes (Cercopithecidæ); (2) The Anthropoid or man-like apes (Simiidæ), which have no tails; and (3) The Hominidæ (Man).

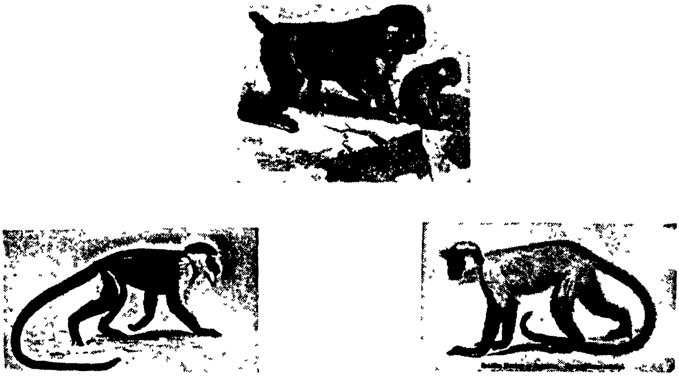


FIG. 137.—A Group of Tailed Apes.

Under (1), the Cercopithecidæ, we will notice three kinds.

In Fig. 137 the Tcheli monkey, on the top, is striking in many points—its dog-like body, its short tail, its baby-like hands, and its John-Bull expression. It is found in North China; and, like the tiger of the same region, has an extra thick fur to enable it to bear the bitter winters. On the left is the Diana monkey of the genus limited to Africa. It has quite a respectable professional air, with its fine white beard and aquiline nose. On the right is the Entellus, one of the sacred apes of India.

Passing to the second family (the Simiidæ), we come

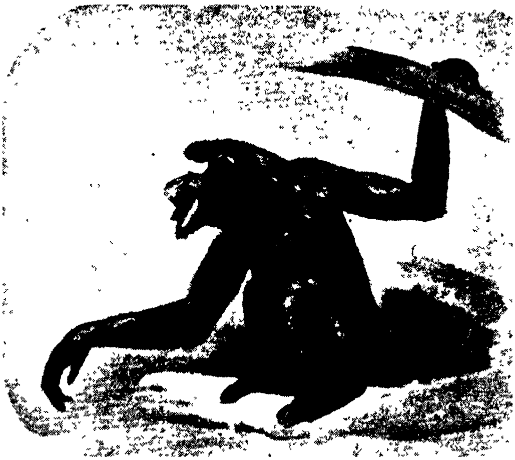


FIG. 138.—The Hoolock, one of the Gibbons.

to the man-like apes. They differ from the former in but few points, yet have moved in the direction of the human form. "In this family the tail is completely absent, the arms are longer than the legs, and the gait might be described as that of a baby learning to walk. They never go completely on all-fours, but usually shuffle along unsteadily on their two feet, which, like those of a baby, show a tendency to turn inwards under them; they usually steady themselves either by means of a stick or by bending forward so that their knuckles touch the ground" (Shipley and MacBride).

Dr. Beddard indicates some of the points in which this family of man-like apes resembles man, thus: "Though they live in trees for the most part, yet when on the ground they progress in a semi-erect fashion. When they put their hands on the ground to aid them in walking, they do not rest, as do the lower apes, on the flat of the hand, but upon the back of the fingers. The hand, in fact, is growing less like a foot in its use."

None of the Simiidæ has a tail or cheek pouches. The hair is rather more scanty than in the former family. The placenta, or after-birth, differs in detail from that of the lower apes, and is exactly like that of man.

Their arms have a greater length as compared with their legs than the family below them. The Simiidæ are divided into four groups: Gibbons, Gorillas, Chimpanzees, and Orangs.

The gibbons (Fig. 138), which range through S.E. Asia, are the smallest existing Anthropoid apes; and they are the most truly tree-frequenting of all this family —hence their very long arms. So agile are they in the forest that they can take leaps from branch to branch of 18 to 20 feet. In the midst of one such prodigious leap a gibbon was seen to catch a flying bird with one hand and attain the branch with the other, then, assuming a sitting posture, it "instantly bit off the head of the bird, picked its feathers, and then threw it down." When on the ground the gibbons walk erect with the big toes separated, as they are in man when the toes are not cramped by wearing boots. They drink in two ways: either by stooping and sucking up the water, or by scooping it up in the hand. The Siamang gibbon invariably lifts the water up to its mouth by dipping in its half-closed hand and then licking the drops off its fingers. Beddard describes the gorilla (Figs. 139 and 140) thus: "The face is naked and black; the skin generally is deep black, even at birth. The ear is small;

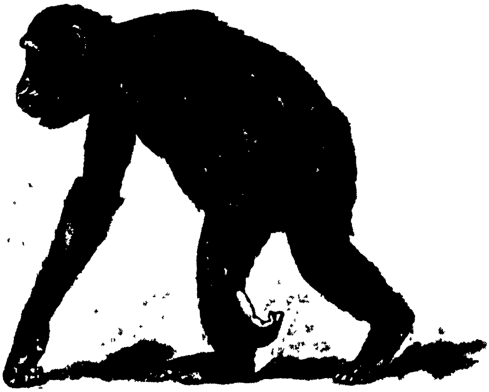


FIG. 139.—Gorilla.

it is more human in form than that of the chimpanzee. The nose has a median ridge; the nostrils are very wide. The hands and feet are short, thick, and broad; and

FIG. 140.—Male Giant Gorilla.

the heel is more apparent than in the other higher apes. This is associated with his mode of walking on a flat foot. It is interesting to find that the muscles of the little toe are diminishing in the gorilla as in man; this is evidently due to leaving trees and walking on the ground, and not to tight boots. In fact, owing to his more erect gait —for he can readily assume the upright posture—many of his muscles are more like those of man."

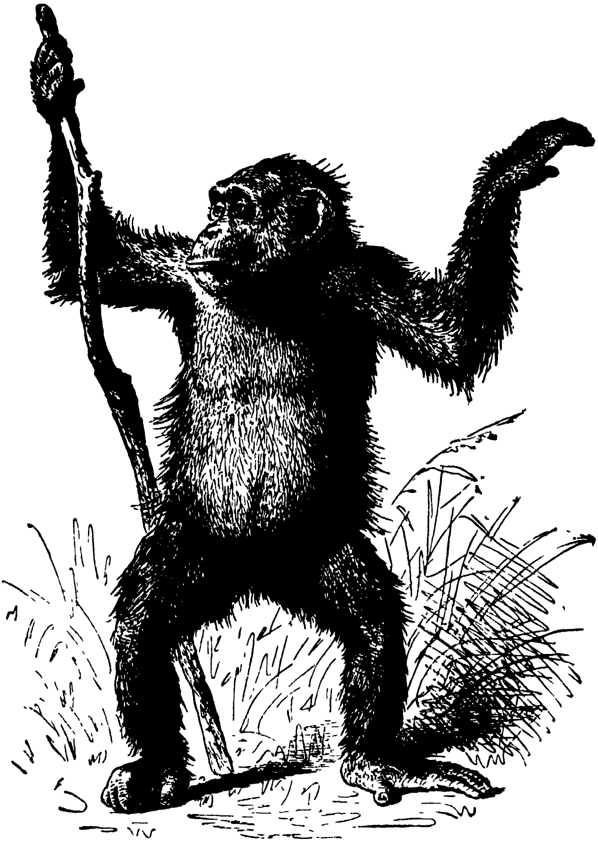


FIG. 141.—Female Chimpanzee.

The gorilla is found only in the forest tract of the Gaboon, Equatorial Africa. It goes about in families, with but *one* adult male, who later has to dispute his position as leader of the band with another male, whom he kills or drives away, or by whom he is killed or driven away. This anthropoid is the largest of all the apes, reaching a height of six feet nine inches.

The chimpanzee (Figs. 141, 144) is also an African animal and in many points resembles the gorilla.

In mental characteristics, however, there is the widest difference between these two apes. The chimpanzee is lively and teachable, but the gorilla is gloomy, ferocious, and almost untamable. Both gorilla and chimpanzee drink by stooping and putting the mouth to water and sucking it up. In captivity, however, they can be taught, especially the chimpanzee, to lift a glass of water to the mouth and drink like a man.

Our last division of these interesting cousins of ours is the orang-utan of Borneo and Sumatra (Fig. 142). It is a large, heavy, pot-bellied ape, with a melancholy expression. The ears, small and not ungraceful, are pressed closely to the sides of the head. The arms are so long that, when the animal is standing, they reach as far as the ankle. The big toe is very short, and usually without a nail. It is important to note the human look in the young head because, in the adult, this is much less marked, owing to the pushing forward of the lower jaw and its great increase in size. Sir Arthur Keith

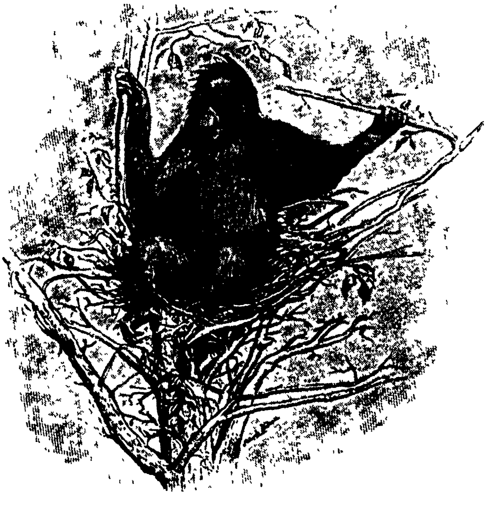


FIG. 142.—Orang sitting in its nest.

emphasizes the great interest of this point, for it indicates that modern man has gained his distinctive facial characteristics by carrying on into adult life certain skull features which are present in apes only during infancy. This

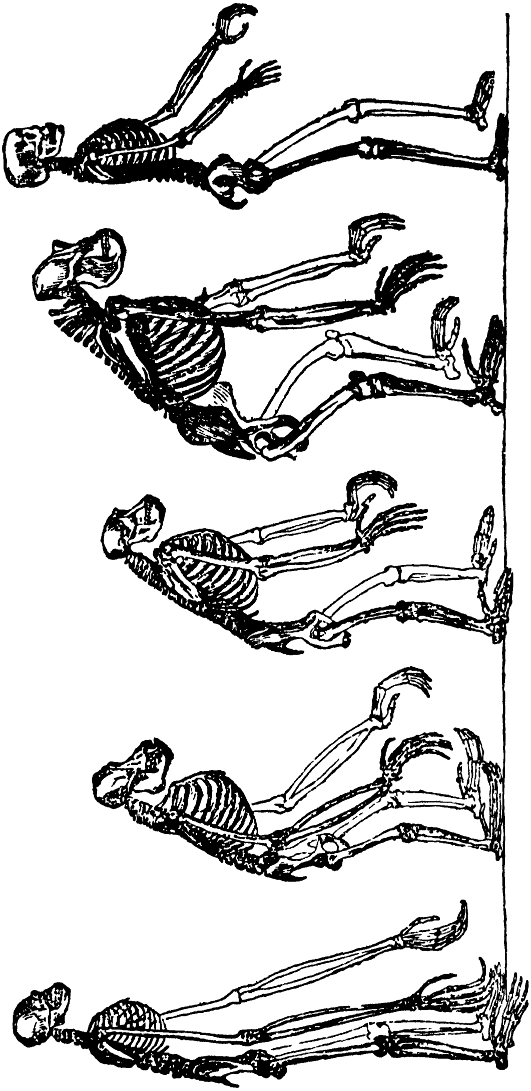


FIG. 143.—Skeletons of Gibbon, Orang, Chimpanzee, Gorilla, and Man.

ape lives mainly in the trees, amid the branches of which it constructs a new nest for itself every other night or so; and it drinks by dipping its hand into water and then

E.N.A.

FIG. 144.—Joe Martin (a seven-year-old performing Chimpanzee).

licking the fingers, but when very thirsty it scoops up water and dribbles it off the hand into its upturned trough-like lips.

Upon carefully studying the skeletons in Fig. 143, few people would doubt that they are all rightly placed in one Order—unless you told them first that one of the skeletons was that of man !

Most of us are now familiar with the intelligent acts performed by monkeys and apes. Natives have trained them to climb coco-nut palms and to select and throw down only the ripe fruit. A baboon in Africa was taught to manipulate correctly the levers in a railway signal box that controlled the shunting points of the lines. Joe Martin (Fig. 144) is perhaps the cleverest animal actor in the world. He is seven years old, and his wedding to " May Brown " was recently solemnized in the New York Zoo. He has on several occasions played important parts in moving pictures and can do almost anything but talk. That he was insured for £10,000, " 'tis true "; and that apes are so dear and men so cheap " 'tis true 'tis pity ; and pity 'tis, 'tis true ! "

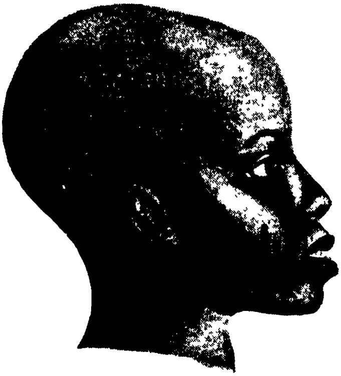


FIG. 145.—A Galla Boy, nine years of age.

Let us now look at a few primitive types of human beings.

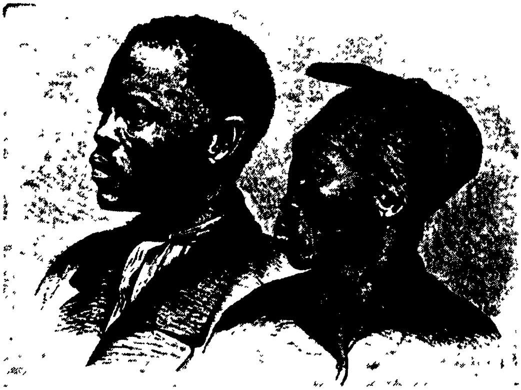


FIG. 146.—A Hottentot Chief and his Wife.

Observe, in the boy in Fig. 145 and in the woman in Fig. 146, the backward-sloping head and the projecting lower jaw and mouth, both ape-like features.

Fig 147 shows a group of natives from the Lake Chad district of Central Africa. In these the ape-like forward projection of the upper lip has been magnified by the adoption of a mouth " ornament."

Before being ashamed of our simian ancestry we ought to study the lower races of men. We should then find that the degrees of differences, mental and physical, between the highest apes and the lowest men are by no means very great. " Some animals have more intelligence than some men," writes Dr. Hornaday, " and some have better morals. I would rather descend from a clean, capable and bright-minded genus of apes than from any unclean, ignorant, and repulsive race of the genus *Homo*. . . . There are millions of members of the human race who are more loathsome and repulsive than wild apes."

E.N.A.

FIG. 147.—A Group of Natives from the Lake Chad Region of French Equatorial Africa.

CHAPTER SIX: AN OUTLINE OF THE LAWS OF EVOLUTION

IN astronomy we saw that heavenly bodies had evolved, and are still evolving, by the condensing of the lightest known gaseous substance. Coming to the earth we saw that its upper crust has been slowly formed, layer upon layer, as a result of cooling. In these layers of rocks we read the tale of life. Beginning at the lowest depths of stratified rocks, we found the remains of animals —but not of the same kind as those now around us. The fossils of that early period tell the story of species that have disappeared. As we come nearer the present surface of the earth, and therefore nearer to modern times, we are impressed by the change which millions of years have produced; the rocks show us fossils more and more like the living things of to-day, till, in the topmost rocks, we find that the animals of a few thousand years ago so closely resembled our own that they can be arranged in the same groups. This shows us that changes from the earliest animals to those of our own time are gradual and connected; it proves that the simple, small forms came first in the world's history, and that, just as the bicycle has gone on improving, so the low forms of animals died out, their place being taken by better forms which had sprung from them by slow changes in advantageous directions. This extinction of so many animal groups is perhaps one of the most astounding and terrible lessons which the rocks teach us.

Further, we have seen in looking at living animals that, if we begin with small creatures which are merely *one* cell of jelly-like matter, we can trace the path of evolution from them up to man, not by a single step, but by multitudes of steps. We have seen that there is no hard-and-fast line betwixt two adjacent groups, since animals occur which are partly like a group below them and partly like a group above.

We saw that a piano and a rifle are the outcome of the bow and arrow. Some of the principles upon which a piano and a rifle are constructed occur in the bow and arrow, though they are somewhat mixed and undeveloped. The bow and arrow in this sense are " generalized "; but after many years of improvements on two quite distinct lines we see two highly specialized instruments—one for producing pleasure in the form of music, the other for causing pain and death—so unlike one another that few people suspect they have had a common origin. This has happened in the few years known to history; what, then, may not have taken place in the evolution of *living* things in millions of years?

In trying to grasp the great principles of evolution we should look at the more primitive animals, and note the points they have in common with the next higher group and also any new points that have appeared in the latter. Thus we form a ladder, and mount step by step to civilized man.

Again, we should examine the several parts of the human body and trace them back to their origin. For instance, the backbone is common to the human race and to all animals above and including the fishes, but we know there was a time before the advent of fishes when no animal had a backbone. Therefore, we assume that all these backboned animals have come from the same group of backboneless ancestors. Then, when we come to examine the various creatures lying, so to speak, in a sort of " no-man's-land "—neutral territory, between the lowest animals with, and the highest animals without, a backbone—we are provided with ample indications of the manner in which so very definite a structure first arose.

Consider the twenty digits, or the four limbs, or the two eyes, or the brain, or, in fact, any other structures. We know that animals lived, and still live, having none of these; and, as we learn more and more about the lowly ancestors of the higher animals, so we discover how such structures were acquired. Of the numerous variations which occurred in the offspring of animals, some perished with the young themselves; but other variations, especially those benefiting the holders in the struggle for life, were handed down to subsequent generations, and so in time became greatly developed and fixed, till, in the course of ages, two distinct sets of animals, originating in the same group, but taking advantage of different variations, became as specialized and unlike each other as pianos and rifles.

To appreciate the relationship that extends through the whole animal kingdom we ought to begin by a study of our own family and relatives. A child may have one striking feature of its father, another of its mother, or blend both so that it shows but little resemblance to either parent—in fact, it presents a new variation. Or there may be some oddity of appearance or manner strikingly like the child's grandparent, or even the grandparent's grandfather. Such features often run through many generations.

One species shades almost imperceptibly into another; one genus, separated from another by thousands of years, is found to have come into being by countless changes—branchings in the tree of life, we might call them. There can be but one explanation of this marvellous network of living and once-living things, to wit, that they are all of one family by descent, and that all the striking changes they.present have come to pass through gradual modifications. It is this " descent by modification " that constitutes " Evolution." Scarcely any well-informed person to-day denies the *fact* of evolution, though he may not admit this or that *method.* Underlying the incontrovertible fact of evolution and explanatory of its *modus operandi* are certain principles, some of which are so invariably and essentially present as to be called *laws.* These principles include: Heredity, Variation, Over-production, Struggle for Existence, Natural Selection, Survival of the Fittest, Elimination of the Unfittest, Over-population, Segregation, Sexual Selection, Artificial Selection, Environmental Pressure, Competition, Atrophy and Hypertrophy, Momentum, Convergence, Mimicry, etc. We will just touch upon some of the more important of them.

(1) *The Law of Heredity.*—Like produces like. Sheep produce sheep; cats, cats; children resemble their parents. This, the law of heredity, has been recognized and acted upon for thousands of years by everyone.

(2) *The Law of Variation.*—The children of the same family are not all *exactly alike,* neither are they exactly like their parents; in short, they *vary.*

This is because the outside forces, which we name environment, are never exactly the same in their action upon different individuals. There are various factors, internal and external, which produce the variations which make evolution possible. If the offspring were always exactly like their parents there could have been no advance, no improvement. This Law of Variation has also been known and recognized for thousands of years.

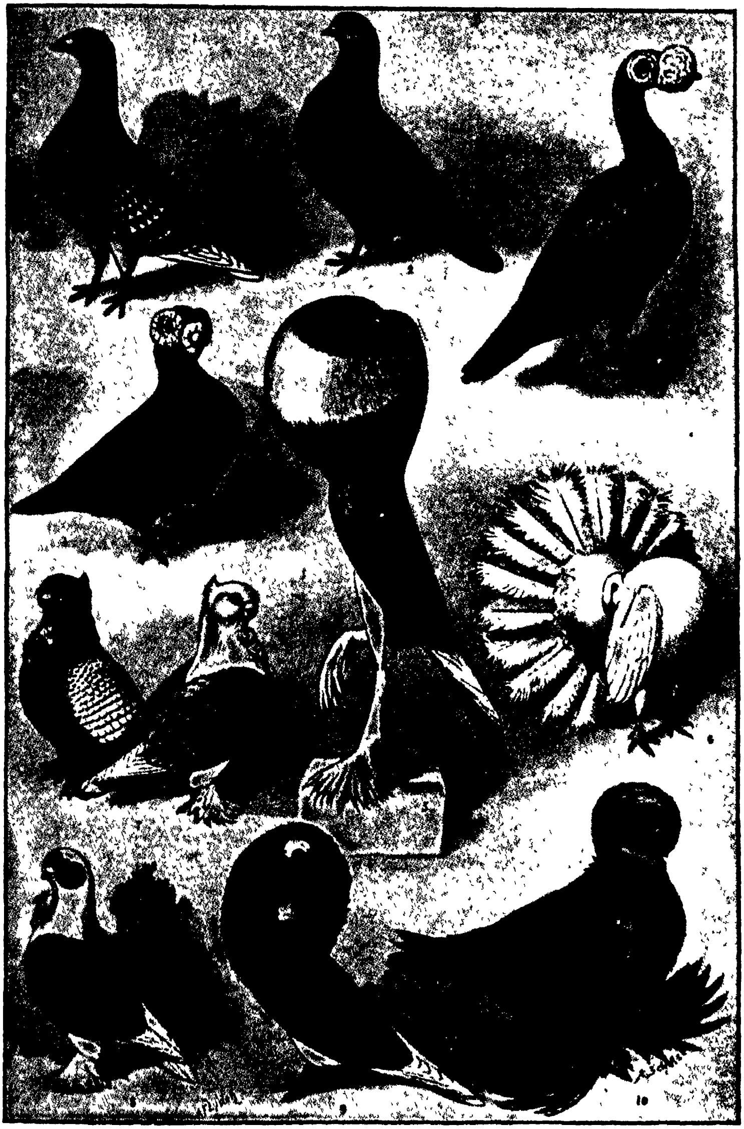


FIG. 148.—A Group of Pigeons.

If any farmer were to kill all his stock which were not exactly like their parents, he would have no stock. The causes of variation are obscure, but all are probably traceable to the action of the environment upon the germ cells of either or both of the parents. Variation is well shown in pigeons. Zoologists are now agreed that all domestic pigeons have been derived from the wild blue rock. Fig. 148 shows a group of pigeons many of which are utterly unlike their wild ancestor.

Look at the pouter, who seems to have swallowed a football, and the fantail, which seems to be trying to bury its head in a fire-screen. By such examples of variations from the same relatively recent ancestors we see that species change and that new ones arise. These changes in pigeons have been brought about chiefly by man's agency; and his acts of choice are called *conscious* or *artificial selection*, for it is man who has selected the points or variations which he wished to develop.

Man selects the points which are to *his own* advantage; " Nature " (if we may be pardoned for personifying these unconscious evolutionary processes) selects the points which are directly to the advantage of the living creature itself and indirectly to that of the species to which it belongs.

(3) *The Law of Over-production and Over-population*; that is, that more of all kinds of living things come into being than can remain alive.

So manifest is this law that it needs little explanation. As Darwin says: " There is no exception to the rule that every organic being naturally increases at so high a rate that, if not destroyed, the earth would soon be covered by the progeny of a single pair." Man has been known to double in twenty-five years, and at this rate, in less than a thousand years there would literally not be standing room for his offspring. What shall we say, then, of such animals as the cod-fish, oyster, and tape-worm, that produce, respectively, a million, two million, and over a thousand million offspring annually? Under no imaginable conditions could all these creatures live and go on reproducing at such a rate in a small world like ours.

(4) *In consequence of more beings coming into existence than can live, there is a Struggle for Existence.*

All organisms naturally try to live, but as there is not sufficient accommodation and food for the vast numbers produced, and as most organisms live upon, or at the expense of, others, it follows that the destruction is on an inconceivably vast scale. In six square feet of ground Darwin found that out of 357 weeds that came up, 295 were destroyed, chiefly by slugs and insects. Not only among lower animals and plants, but among savage and civilized races of men a similar and no less fierce struggle for existence is ever waging.

(5) *In the Struggle for Existence the fittest survive.*

By " fittest " we do not mean the best according to any *ideal* standard, but those most suited to cope with the particular existing circumstances. If you have 1,000 people at a railway station who have been to a football match, and the train can take only 600, clearly 400 will have to stay behind. Do you think the football team would be among the 400 left behind? The players may not be very scientific, philosophical, or poetic men but they have certain qualities which are of great service to people who wish to get into trains; so they are not left behind. Such is the *success of the fittest*!

Again, by Natural Selection we do not mean conscious selection, or design, or conscious working for an end. Darwin's term, " Natural Selection," means that, in a world of struggling beings, natural processes will destroy some and leave others, so that the weak and ill-adapted are weeded out. To give a homely example: one might succeed in rearing chickens and ducks in a small yard in ordinary weather. But if a sudden deluge of rain filled the yard to the depth of two or three feet, the chickens would drown, while the ducks would swim about happily. The ducks would be the fittest to survive a deluge of rain. On the other hand, if these creatures were being reared in a field with very little shelter, the chickens would take to roosting in the hedges or trees, but the ducks would have to remain on the ground where they would fall an easy prey to foxes. Chickens are obviously the fittest to survive in this case. These illustrations are the more interesting because chickens and ducks are nearly related. They come from a common ancestor not very far back—an ancestor that was neither fowl nor duck, yet possessed some points of both.

Now, changes of circumstances such as those just outlined have been constantly taking place for millions of years, and it is quite clear that creatures entirely unfitted for the new circumstances perished. A very small thing might easily determine whether a savage or a poet should live or be destroyed.

Natural Selection is infinitely more powerful, efficacious, wide-reaching, and more lasting in its effects than are the puny efforts of our artificial selections. It works solely upon the single principle—the advantage to the individual. In it is no pity, no mercy, no dream of the good of the whole. Ever it backs up its favourites—those who possess the requisite capacities to live successfully—cherishing them, fostering and furthering their pursuits. With deadly accuracy it eliminates the failures so to live—their mute appeal is invariably met with down-turned thumbs. It sees to it that individuals with favourable variations transmit these to offspring, and thus subsequent generations tend to get better and better adapted to their surroundings.

Those who still argue that we cannot see evolution at work should consider the marvellous products—flowers, fruits, and domestic animals—that are a familiar feature

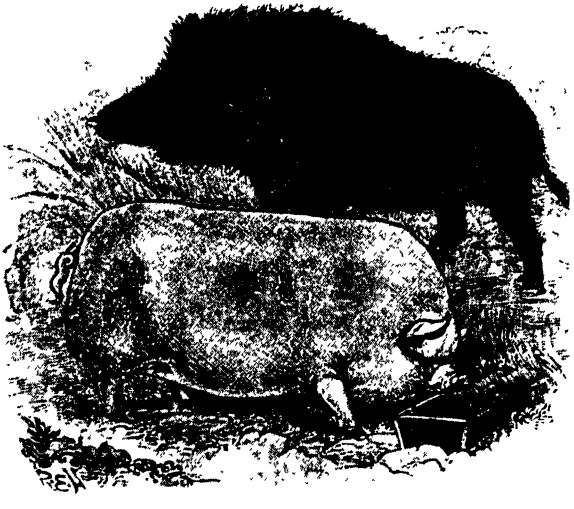


FIG. 149.—Two Pigs. (After *Romanes*.)

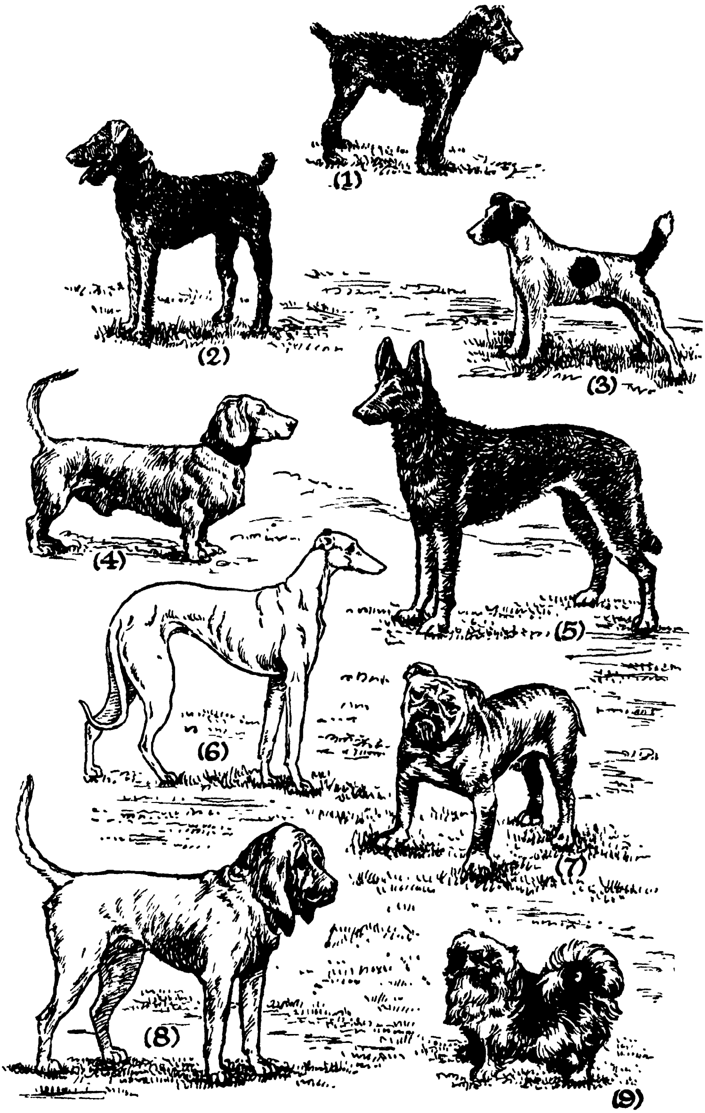


FIG. 150.—A Group of Dogs.

1. Irish Terrier.
2. Airedale.
3. Smooth Fox Terrier.
4. Dachshund.
5. Alsatian.
6. Greyhound.
7. Bulldog.
8. Bloodhound.
9. Pekinese.

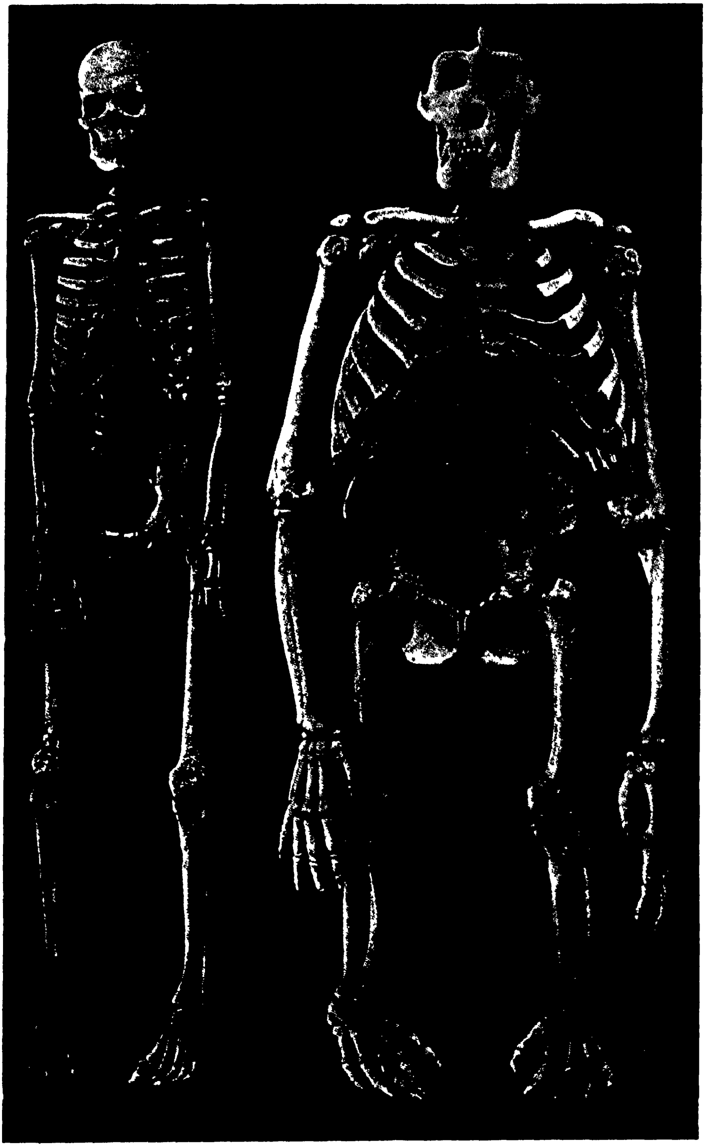


FIG. 151.—Skeletons of Man and Gorilla.

of modern civilization, though quite unknown in the days of Queen Elizabeth.

The animals in Fig. 149 are both pigs. Man, in a comparatively few years, has evolved the white domesticated pig from the very unlike black wild hog.

No one supposes that each kind of dog in the group shown in Fig. 150 was separately and specially created. These very dissimilar animals if found wild would be classified as different species, yet they belong to one family, the *Canidæ*, which includes foxes, wolves, jackals, and dogs—all descendants of some common *Thooid* or wolf-like ancestor resembling, if not identifiable with, the Eocene Cynodictis.

Again, in the case of domestic fowls we see how new and distinct varieties are formed by fanciers selecting the variations they desire. The old notion that species are fixed is, then, not true, for they can be modified in many ways. The various kinds of animals have evolved to their present state in consequence of the repeated selection of certain of these modifications.

The many points of likeness between man and some lower animal constitute striking evidence of that common descent which evolution teaches. Both require food, digest it, and throw out waste products. Both die if cut off from air. Both must have rest and sleep, both grow from infancy to maturity, reproduce their kind, suffer the decay of old age, and finally die. So akin are man and the higher mammals that they are subject to many of the same diseases—pneumonia, tuberculosis, anthrax, glanders, hydrophobia, rheumatism, and even measles! The higher we go in the animal scale, the more striking and detailed do such resemblances become.

The skeletons of man and ape shown in Fig. 151 exhibit a remarkable similarity in general plan. If you fix your attention on any bone or arrangement of bones you will find it paralleled in the other skeleton.

So, too, if with the skeleton of man you compare that of a fish, frog, lizard, rabbit, and lemur, you will find that, while all present resemblances, these become more and more marked as we pass up the series in the order mentioned.

CHAPTER SEVEN: DEVELOPMENT AND VARIATION

MOST minds are hostile to new ideas because the human brain is a relatively recent and imperfectly developed instrument. Since all intelligence results from the action of outside forces upon the nervous system, it is manifest that, following the impact of a new set of forces upon the brain, there is liable to ensue something of the nature of a shock. This explains why one's mental *attitude* so largely determines the power to receive fresh ideas. All people are capable of understanding " Evolution," but many approach the subject with a fixed desire to destroy rather than to comprehend it.

Those who have been taught incorrect surmises about the beginnings of the earth and of man are handicapped at the start by enemies, in the shape of pre-conceived ideas, which contest every approach of truth and constitute a far more formidable barrier than mere ignorance. So long, however, as false explanations of the world are deemed good enough for children, such enemies will drag the human race in captive chains.

" Early ideas are not usually true ideas. Undeveloped intellect, be it that of an individual or that of the race, forms conclusions which require to be revised and re-revised before they reach a tolerable correspondence with realities. Were it otherwise, there would be no discovery, no increase of intelligence. What we call the progress of knowledge is the bringing of thoughts into harmony with things; and it implies that the first thoughts are either wholly out of harmony with things or in very incomplete harmony with them. If illustrations be needed, the history of every science furnishes them. The primitive notions of mankind as to the structure of the heavens were wrong; and the notions which replaced them were successively less wrong. The original belief respecting the form of the earth was wrong, and this wrong belief survived through the first civilizations." (Herbert Spencer.)

Many people are still satisfied with the " early ideas " of man when he was but little better than a savage, and speak of comets, witches, and ghosts in the ignorant manner of the lowest races. Such people are thousands of years behind science, and to them half the world has no meaning. One of these " early ideas " is that each species was separately created, and has remained the same ever since. The life of man is so short that only in such instances as certain bacteria, the shelled amœba *Difflugia Corona*, the fruit-fly *Drosophila*, and the Porto-Santo rabbit, has the production of new types been actually observed. Man is apt to flatter himself as being the latest product of evolution, but the human louse—which is dependent upon man—is a much later product. Yet more significant is the fact that the lice of man have their nearest relatives, not in those of birds or dogs, *but in the lice of monkeys and apes*! The same species of louse is found upon closely related species of animals, even though these may be widely separated, as in the case of the N. American and Egyptian kingfishers, or the N. American and Siberian ground squirrels.

Here it will be well to explain that what is meant by this very arbitrary word *species* is a group of living individuals resembling each other closely, the several members of which can interbreed and produce potentially fertile offspring. Some of the extremes of our domestic dogs, for instance mastiff and toy-terrier, could not, for physical reasons, breed together; others, if interbred, would beget infertile offspring just as the horse and ass beget the infertile mule. So we should be quite justified in regarding the mastiff and toy-terrier as belonging to the same genus but to different species; indeed, they are new species evolved through man's agency. The animals and plants of our farms and gardens are proof of the many existent *varieties* which, in a few years, man has brought into being, and these are the actual stepping-stones to *new species*. We must remember, however, that the grouping of animals and plants in species is no *natural* division, but a labour-saving device to help in classification. Two methods are used by biologists in this process; the living things may be grouped together in accordance with their actual relationship, or from the standpoint of their life conditions; the former method is termed *Taxonomy*, the latter, *Bionomics*. An example of the complete classification of some animal, say, a tiger, may be of use to the student.

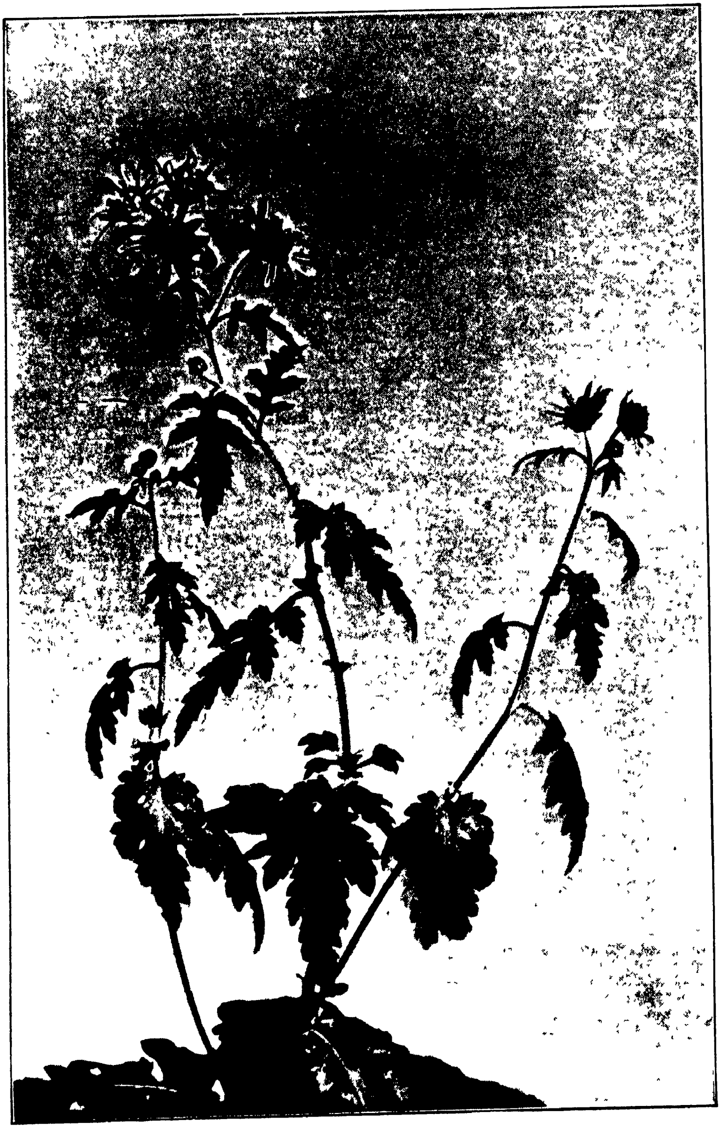


FIG. 152.—*Chrysanthemum Indicum.*

Individual. A tiger at the Zoo.
Variety. The cave tiger or the jungle tiger.
Species. *Felis tigris*, or *Felis domestica.*
Genus. *Felis.*
Family. *Felidæ*—cat, lion, leopard, jaguar, cheetah, ounce, ocelot, and lynx.
Order. *Carnivora* (flesh-eaters).
Class. *Mammalia* (suckle their young).
Section. *Craniata* (possess a definite head).
Sub-phylum. *Vertebrata* (possess a backbone).
Phylum. *Chordata* (possess a notochord).
Sub-kingdom. *Metazoa* (multicellular).
Kingdom. *Animalia* (an animal).
World. *Organic* (it is alive).

FIG. 153.—Chrysanthemum.

Few people would be able to recognize in Fig. 152 (*Chrysanthemum Indicum*) the ancestor of our modern Chrysanthemum (Fig. 153). The latter shows what man can do by selecting and propagating variations which are favourable to his purpose, though by no means to the plant's welfare from Nature's view-point. The half-lop rabbit shown in Fig. 154 exemplifies what Artificial Selection can effect in the animal world.

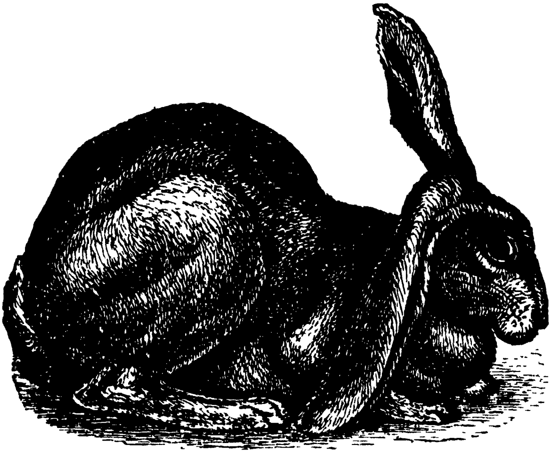


FIG. 154.—Half-lop Rabbit.

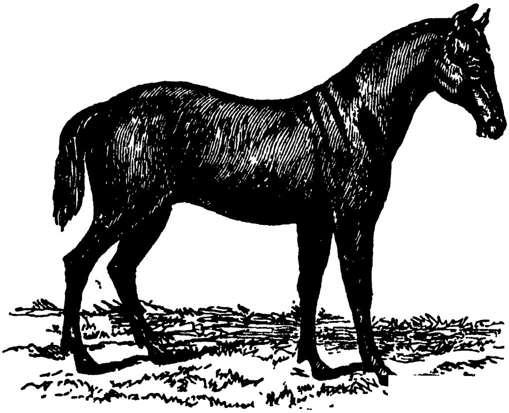


FIG. 155.—Devonshire Pony, showing ancestral Stripes.

In Fig. 155 you see a pony with zebra-like stripes on its shoulders and fore-legs. Such stripes—the marks of wild ancestors—will sometimes appear in horses and donkeys though neither parents nor grandparents had

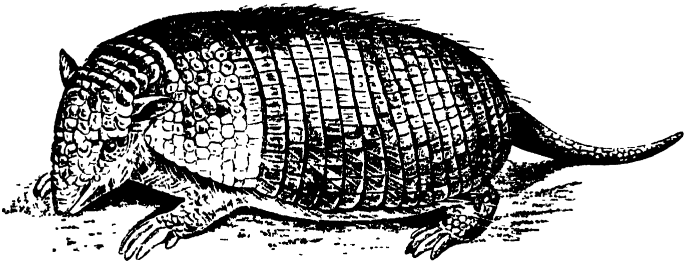


FIG. 156.—Armadillo.

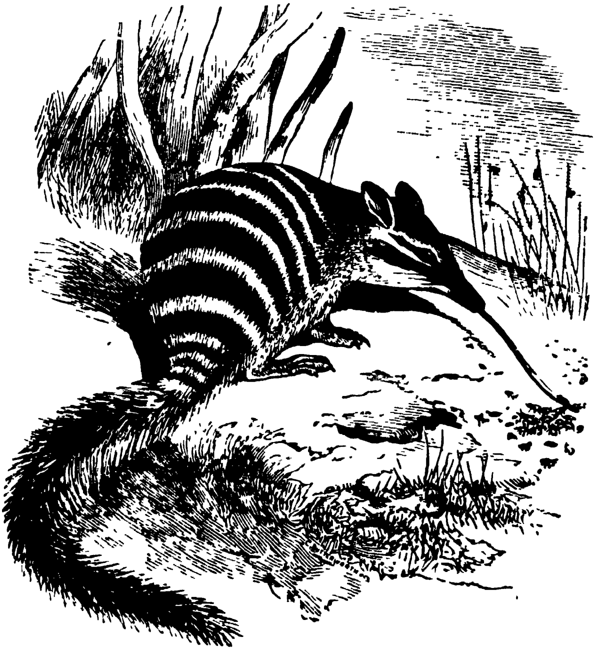


FIG. 157.—Banded Ant-eater (*Myrmecobius fasciatus*).

them. This form of variation is called an "atavism" (Lat. *atavus*, forefather) or "reversion"—in breeders' parlance, a "throw-back." All kinds of animals are liable to show this remarkable trait. A lizard that has lost its tail sometimes grows a new one bearing scales like those of an ancestral species. The primitive blue-rock colour sometimes turns up unexpectedly in an apparently pure fancy breed of pigeon. Children born of sickly parents often exhibit ape-like features, and certain parts of the brain of some insane people and criminals are undoubtedly reversions. Dapples on horses, as previously stated, are probably relics of ancestral skin-plates. *All* mammals have come from a group of scaly reptiles. The armadillo (Fig. 156) is a mammal in which hairs can be seen growing between the scale-like plates. In some mammalian ancestors the hair used to grow round each scale, in others between the rows of scales. The hair in the modern descendants of the former shows a dappling arrangement (the Dasyure); of the latter, a striped arrangement (Myrmecobius) (Fig. 157). The scaly pangolin (Fig. 158) has hairs between the plates when it is young, but in the adult the hair is glued together to form overlapping scales. It is a true tree-climbing ant-eater, belonging to the primitive order *Edentata* (toothless).

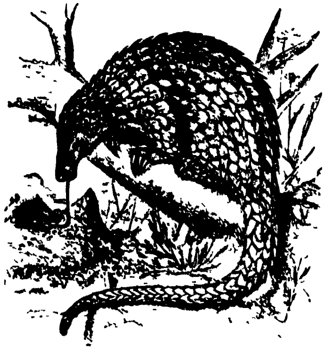


FIG. 158.—White-bellied Pangolin.

That strange group, the modified mammals (Metatheria), to which the banded ant-eater (Fig. 157) just alluded to belongs, includes the curious pouched mammals of Australia and neighbouring islands as well as the opossums of America.

KINDS OF DEVELOPMENT

Every individual, in its growth from a fertilized egg to an adult, repeats to a great extent those several stages through which its ancestral line has passed. This process is called " the fundamental law of biogeny," or the " biogenetic law," and it may be summarized in Haeckel's words thus: "*Ontogeny is a brief and condensed recapitulation of Phylogeny.*" Were each human being in its ontogeny to repeat, even perfunctorily, every stage of its million centuries' phylogeny it would require more like nine years' than nine months' gestation. But the human embryo, in common with every other embryo, has learnt, by various adaptations (*cenogenesis*), to get quickly to its full development; it has made short cuts, so to speak, in its *palingenesis*.

In fine, certain of the stages of growth manifested by the embryo (especially that of the later and higher animals) are not recapitulations of a remote past, but are definite modern adaptations to the altered conditions of a fast-changing environment.

Here it will be well to explain certain words just used:

Biogenesis (*bios*, life; *genesis*, origin). The origin and development of living things.

Cenogenesis (*kainos*, new). The introduction of new features or structures whereby the embryo can hasten on its ontogenesis.

Ontogenesis (*on*, organism). The development of the individual organism—its embryology and growth.

Palingenesis (*palin*, again). The recapitulated racial history by the individual organism, especially during its prenatal development.

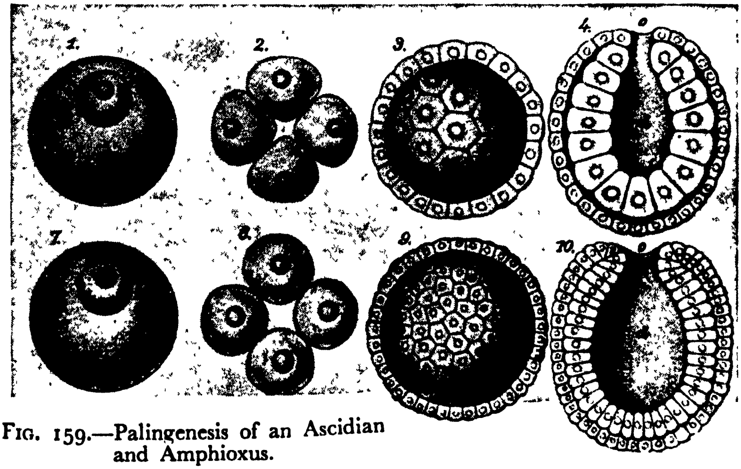


FIG. 159.—Palingenesis of an Ascidian and Amphioxus.

Phylogenesis (*phylon*, race). The development or life-history of the race, that is, the ancestral history of an organism. Just as Embryology is the science of Ontogeny, so Palæontology is the science of Phylogeny.

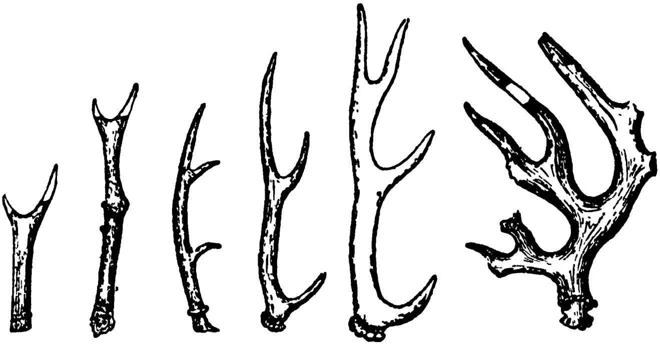


Fig. 160.—Fossil Antlers.

In Fig. 159 the top row shows the palingenesis of an Ascidian, and the bottom row that of Amphioxus. It will be seen that the recapitulations of the ancestral histories are practically alike. All animals above Ascidians pass through similar stages.

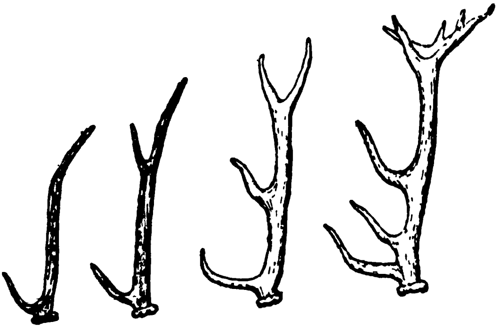


Fig. 161.—Antlers of one Deer.

In order to understand more clearly what is meant by phylogeny and ontogeny, we may study Figs. 160 and 161.

In Fig. 160 we see the fossil antlers of deer; they well represent the phylogenetical development of these structures.

Fig. 161 depicts the ontogenetical development of the antler of *one* deer as it grows, year by year, till from a short spike or tine it becomes the highly-branched antler. The large group of animals that includes sheep, deer, camels, oxen, etc. is called "Ruminants." The first ruminants were hornless. In the early Miocene period deer had no antlers, but by the mid-Miocene they possessed two-pronged ones; and the higher we ascend in the subsequent beds of rock the more prongs are found, till in the first-bed of Norfolk are found the many-pronged antlers.

Turning again to Fig. 161, we see the antler as it grows in any single stag. The one-tine form has not as yet been found among fossils; but in all the rest we see that the history of the individual is a repetition of that of the race—ontogeny recapitulates phylogeny.

A still more striking case of this law is found in the history of fish-tails.

"Among fishes," says Professor Le Conte, "there are two styles of tail-fins. These are the even-lobed, or homocercal (Fig. 162), and the uneven-lobed, or heterocercal (Fig. 163). The one is characteristic of ordinary fishes (teleosts), the other of sharks and some other orders. In structure the difference is even more fundamental than in form. In the former style the backbone stops abruptly in a series of short, enlarged joints, and thence sends off rays to form the tail-fin (Fig. 162); in the latter the backbone runs through the fin to its very point, growing slenderer by degrees, and giving off rays above

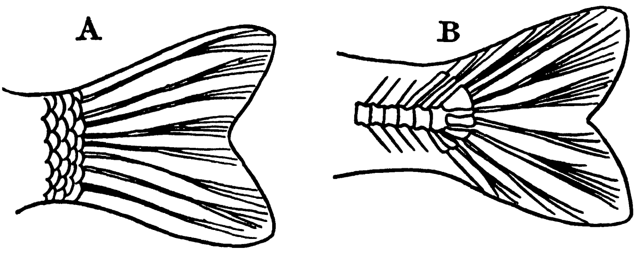


Fig. 162.—Homocercal Tail, showing (A) external form and (B) internal structure.

and below from each joint, but the rays on the lower side are much longer (Fig. 163). This type of fin is, therefore, *vertebrated*, the other *non-vertebrated*. . . . But there

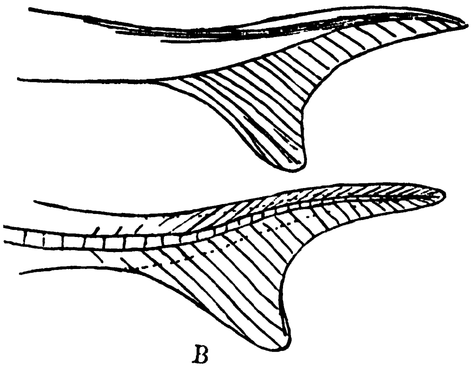


Fig. 163.—Heterocercal Tail: (A) external form, (B) internal structure.

is still another type, found only in the lowest and most generalized forms of fishes. In these the tail-fin is vertebrated and yet symmetrical. This type is shown in Fig. 164.

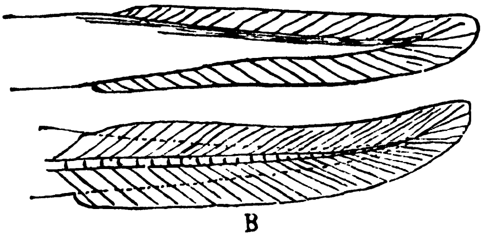


Fig. 164.—Vertebrated yet symmetrical Fin: (A) external form, (B) internal structure.

" Now, in the development of a teleost fish (Fig. 162) . . . the tail-fin is first like Fig. 164; then becomes heterocercal, like Fig. 163; and finally becomes homocercal, like Fig. 162. Why so? Not because there is any special advantage in this succession of forms; for the changes take place either in the egg or else in very early embryonic states. The answer is found in the fact that *this is the order of change in the phylogenetic series. . . .* The earliest fish-tails were almost certainly like Fig. 164; then they became like Fig. 163; and, finally, only much later in geological history (Jurassic or Cretaceous), they became like Fig. 162. This order of change is still retained in the embryonic development of the last introduced and most specialized order of existing fishes. The family history (phylogeny) is repeated in the individual history (ontogeny).

"Similar changes have taken place in the form and structure of birds' tails. The earliest known bird—the Jurassic Archæopteryx—had a long reptilian tail of twenty-one joints, each joint bearing a feather on each side, right and left (Fig. 165 I). See also Fig. 115.

"In the typical modern bird, on the contrary, the tail-joints are diminished in number, shortened up, and enlarged, and give out long feathers, fan-like, to form

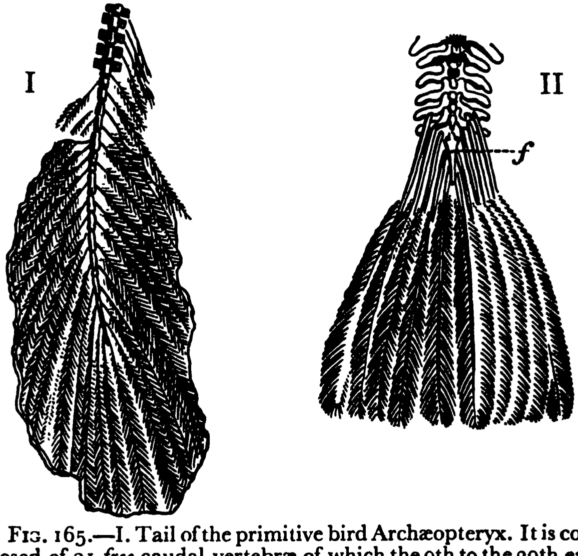


FIG. 165.—I. Tail of the primitive bird Archæopteryx. It is composed of 21 *free* caudal vertebræ of which the 9th to the 20th each supports a pair of feathers. II. Tail of a modern bird. It is made up of about 18 caudal vertebræ of which 6 are fused with the sacrum, 6 are free, and 6 go to the formation of a triangular-shaped bony mass known as the *pygostyle* (*f*) which carries the tail-feathers.

the so-called tail (Fig. 165 II). The Archæopteryx tail is *vertebrated*, the typical bird's *non-vertebrated*. This shortening up did not take place at once, but gradually. The Cretaceous birds, intermediate in time, had tails intermediate in structure. The Hesperornis (Fig. 71) had twelve joints. At first—in Jurassic strata—the tail is fully a half of the whole vertebral column. It then gradually shortens up until it becomes the aborted organ of typical modern birds. Now, in embryonic development the tail of the modern typical bird *passes through all these stages*. At first the tail is nearly one-half the whole vertebral column; then, as development goes on, while the rest of the body grows, the growth of the tail stops, and thus finally becomes the aborted organ we now find. The ontogeny still passes through the stages of the phylogeny. The same is true of all tailless animals."

DIFFICULTIES

Ever since 1859, when Darwin convinced thoughtful men that the master-key to all cosmic problems was Evolution, biologists have been emphasizing the facts that it does not proceed in a straight line to something "better" in every single instance; that man has not come from any existing order of ape; that survival of the fittest does not mean survival of the loveliest, noblest, or tenderest; that Natural Selection is neither the *sole* nor even the necessary moulder of the world, nor is it a teleological, that is, a conscious and purposive selection; that relatively persistent species are not absolutely *immutable* species.

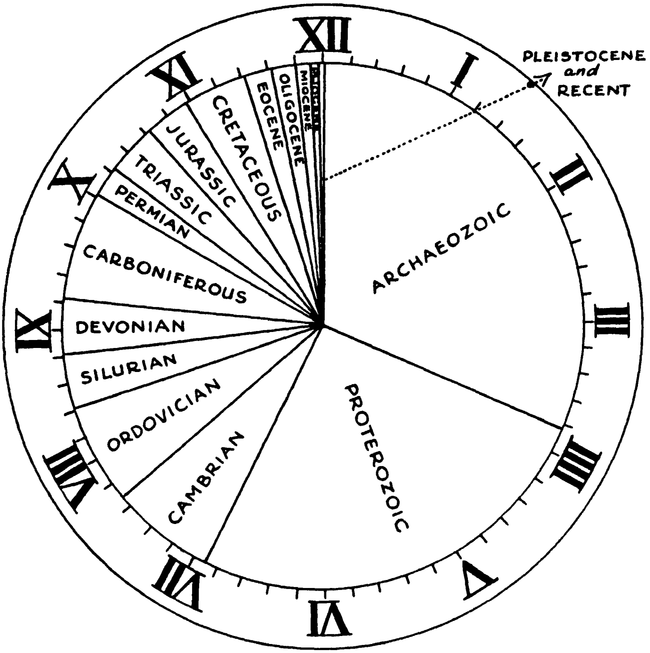
All these cautions against error have been available to the reading public for over half a century; yet if one meets with an objection to Evolution it is almost certain to be one of these. Anti-evolutionists are apt to talk glibly of missing links without the least idea as to what it is they mean by the expression; they argue that because man has no tail he cannot be related to the apes, overlooking the obvious fact that if he was tailed his condition would constitute a very powerful argument against close relationship to the apes, for they are tailless!

TIME

The vast period of time required to meet the demands of the biologist used to be, but is no longer, a difficulty. There are, however, other points with regard to time that are of intense interest to us, such as the time when man first appeared on the earth, the time when the latter cast off the moon, and was cast off from the sun. None of these dates is *absolutely* settled, but astronomers can give us a very fair idea of the *relative* periods involved.

The question of the time-duration of life is one that has been carefully studied along two different lines, biological and physico-chemical. In the last few years physicists and chemists, supported with overwhelming evidence from the radio-active elements, have enormously extended the earth's life-bearing period. Whereas twenty years ago fifty million years was considered a somewhat audacious demand for this, Professor Holmes now tells us that the age of the earth is between 1600 million and 3000 million years and that probably some 1260 million years have elapsed since Lower pre-Cambrian times. By taking a mean of numbers given by various scientists we may safely assume that life of some sort has existed on this planet for 1250 million years. It is difficult to form any conception of so vast a period as this, but the following scheme may help. Following Haeckel, let us call the whole life-history of the earth one cosmic day, and make 12 hours correspond to 1250 million years, 1 hour to approximately 104 million years, a minute to about one and three-quarter million years, and a second to approximately 28,000 years. If now we reduce the geological formations to this one-round-of-the-clock scale we obtain some very impressive results. Life started at midnight, while 12 o'clock noon represents present time. The first point to be noticed is that the very simple types of living things which dwelt in the pre-Cambrian seas of the Archæozoic and Proterozoic ages occupy over one half of the total life-bearing history. Chordate animals only begin to appear about 7.30 a.m.

Lung fishes come on the scene about 8.40 a.m. About 9 a.m. the Amphibians appear and the first known land-flowers begin to brighten the earth. Some twenty-five minutes later reptiles are crawling about. At 10.10 a.m. reptile-mammals come on the stage, followed, at about 10.30 a.m., by the reptile-birds. At 10.50 a.m. the Lords of Creation are the giant saurians, but they have gone the way of all flesh by 11.10 a.m. Five minutes later egg-laying mammals are well to the fore, followed in a few minutes by the placental mammals.



By 11.24 a.m. miniature elephants and horses are in being; but not until 11.30 a.m. does the lowest Primate (lemur) show itself—to be accompanied, in another five minutes, by the first monkeys. At 11.38 a.m. apes appear; and by 11.50 a.m. ancestors of our gorilla, chimpanzee, orang-utan, and gibbon are climbing about the Miocene forests. At 11.52 a.m. we catch a fleeting glimpse of the first known humanoid, *Pithecanthropus erectus*, slouching about the Siwalik valleys of Java. About four minutes later we are witnessing the transformation of the more ape-like creatures into the more man-like ones. At 11.57 a.m. tool-using man is on the

scene. At a minute to midday the prevailing glacial conditions are causing an almost wholesale extinction of the great mammals. Just about one second before the clock strikes 12 noon, historic man appears. In this last second are crammed all the marvellous discoveries and feats of *Homo sapiens*, from the building of the Great Pyramid by Cheops to the formulation of such theories as those of Natural Selection by Darwin and Wallace, of Quanta by Planck, and Neo-Relativity by Einstein.

Period.	Duration in years.	No. of years ago to commencement of period.	Duration on 12-hour clock scale.	Time on clock when period began.
			H. M. Sec.	H. M. Sec.
Present Day	—	—	—	12 0 0
Recent	20,000	20,000	0 0 0·7	11 59 58
Pleistocene	980,000	1,000,000	0 0 34	11 59 25
Pliocene	7,000,000	8,000,000	0 4 2	11 55 23
Miocene	12,000,000	20,000,000	0 6 54	11 48 28
Oligocene	15,000,000	35,000,000	0 8 38	11 39 50
Eocene	25,000,000	60,000,000	0 14 24	11 25 26
Cretaceous	50,000,000	110,000,000	0 28 48	10 56 38
Jurassic	30,000,000	140,000,000	0 17 17	10 39 21
Triassic	40,000,000	180,000,000	0 23 2	10 16 18
Permian	25,000,000	205,000,000	0 14 24	10 1 54
Carboniferous	80,000,000	285,000,000	0 46 2	9 15 51
Devonian	45,000,000	330,000,000	0 26 0	8 49 56
Silurian	40,000,000	370,000,000	0 23 0	8 26 53
Ordovician	78,000,000	448,000,000	0 45 0	7 41 57
Cambrian	77,000,000	525,000,000	0 44 18	6 54 0
Proterozoic	325,000,000	850,000,000	3 7 12	3 50 24
Archæozoic	400,000,000	1250,000,000	3 50 24	12 0 0
Total	1,250,000,000	—	12 0 0	—

CHAPTER EIGHT: COMPARATIVE ANATOMY

A FEW vain people are still hurt when they learn for the first time how closely their bodies resemble those of lower animals in consequence of descent from a common ancestor.

It is well known that man and the horse have both come from the same early group of animals. If we were to trace their ancestors far enough back, we should see that they and all other mammals have come through the Theromorpha or mammal-like reptiles. It is, therefore, interesting to take the skeleton of the horse and compare it, bone by bone, with that of man (Fig. 166). The first striking thing is that both have almost exactly similar bones; their skeletons must, therefore, have been acquired *before* their ancestors parted to go on separate lines of evolution.

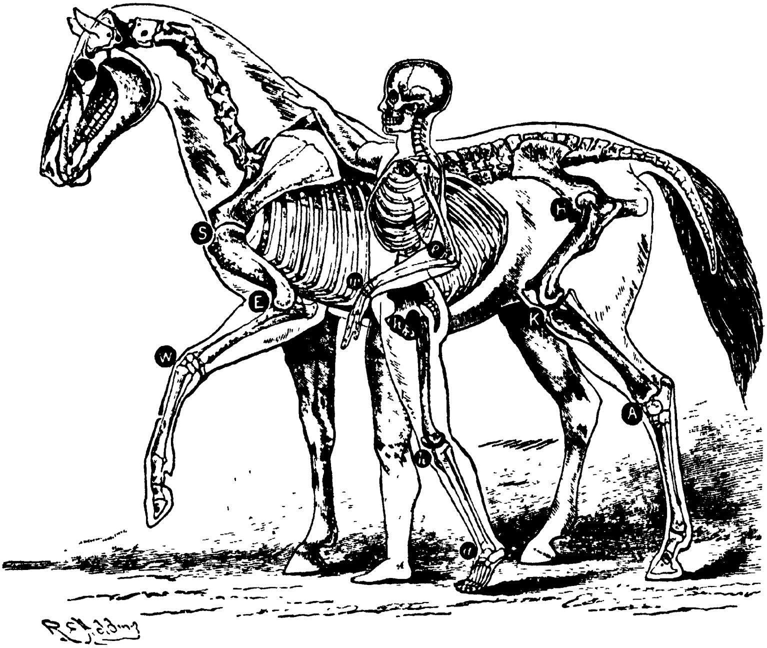


FIG. 166.—Comparative View of the Skeleton of Man and Horse. S, shoulder joint; E, elbow joint; W, wrist joint (knee in horse); H, hip joint; K, knee joint (stifle); A, ankle joint (hock).

We should see the similarity of the skeletons even better had the man been shown resting on fingers and toes in the quadrupedal position. Some animals, such as man and the bear, have a *plantigrade* gait, that is, they walk on the flat of the foot; others, such as the horse, have a *digitigrade* gait, that is, they walk on the tips of their digits.

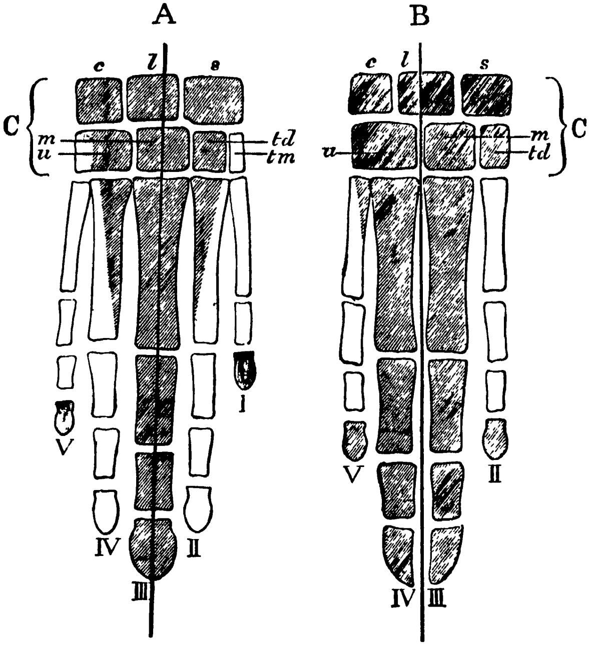


FIG. 167.—Diagrammatic Representation of the Bones of the Foot. A, diagrammatic representation of the bones of the right fore-foot of an odd-toed or perissodactyle animal; B, of an even-toed or artiodactyle animal; C, the carpus or wrist, consisting of two rows of bones, the upper being *c*, cuneiform: *l*, lunar; and *s*, scaphoid: the lower, *u*, unciform; *m*, magnum; *td*, trapezoid; and *tm*, trapezium. The long bones in contact with the last constitute the metacarpus; the remaining bones are the phalanges. The digits or toes are numbered in order from the inner to the outer side of the foot. The shaded parts of A are those that are present in the horse; in B, those that are present in the ox. (After *Flower*.)

The horse belongs to the large group of hoofed animals, the Ungulates. This group is divided into the even-toed or Artiodactyles and the odd-toed or Perissodactyles (Greek *artios*, even; *perissos*, uneven; *daktylos*, digit).

The artiodactyles (even-toed) include the pig, deer, ox, sheep, goat, camel, giraffe, hippopotamus. Their feet are formed on the plan of B in Fig. 167.

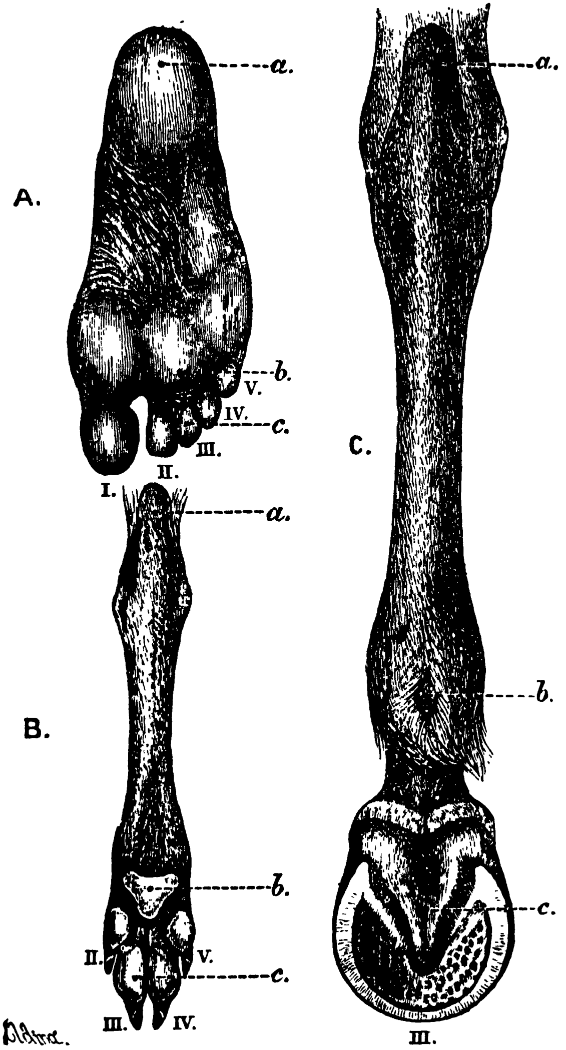


FIG. 168.—Plantar surface of the Foot of (A) Man, (B) Dog, (C) Horse. The letters *a*, *b*, and *c* indicate the corresponding points of the three.

The perissodactyles (odd-toed) include the horse, tapir, rhinoceros, elephant. Their feet are formed on the plan of A in Fig. 167.

In Fig. 168, A shows the human foot; B and C show what would be the foot used by the dog and the horse if they walked as man does, instead of using only their toes. It is very interesting to compare these three feet, and especially to note *b* in the horse; this is the ergot, usually concealed in the hair; it is useless, a relic of a pressure pad corresponding to that in the dog's foot

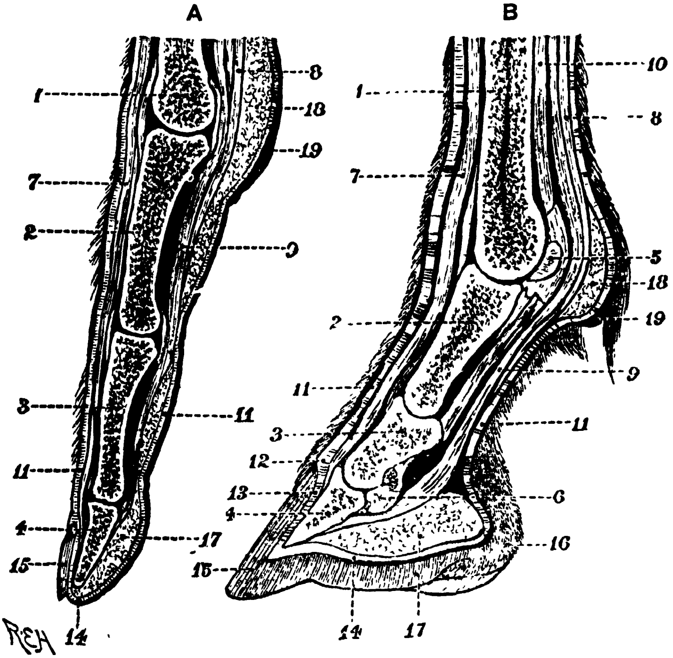


Fig. 169.—A, Section of the Finger of Man; B, Section of the Foot of Horse. In both A and B—1, metacarpal bone; 2, first phalanx; 3, second phalanx; 4, third or ungual phalanx. In A—7, tendon of extensor muscle; 8, tendon of superficial flexor; 9, tendon of deep flexor; 11 and 14, derm or true skin; 15, nail; 17, fibro-fatty cushion of end of finger; 18, ditto of palm behind meta-carpo-phalangeal joint; 19, thickened skin covering of same. In B—5, one of the upper sesamoid bones; 6, lower sesamoid; 7, 8, and 9, same as in A; 10, short flexor of fetlock; 11, derm or true skin; 12, coronary cushion; 13, laminal; 14, villous portion of the hoof matrix; 15, hoof; 16, the heel; 17, plantar cushion; 18, fibro-fatty cushion of the fetlock; 19, bare patch with thickened skin covering or "spur." (After *Flower*.) The corresponding parts of A and B have the same numbers.

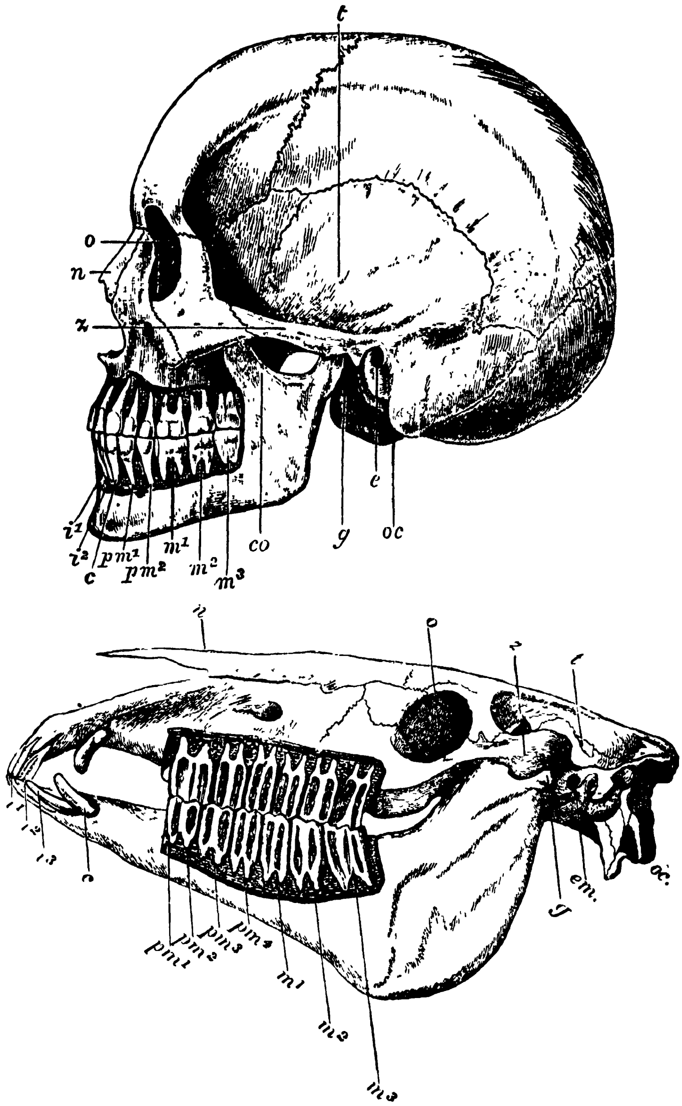


FIG. 170.—Skull of Man and (below) Horse.

Side view with the bone removed so as to show the whole of the teeth. The same letters refer to the same parts in both. *n*, nasal bone; *o*, eye; *z*, zygomatic arch; *t*, temporal fossa; *oc*, occipital condyle; *e* or *em*, external opening of ear; *g*, glenoid fossa for articulation of the lower jaw. Teeth: *i*, incisors; *c*, canine; *pm*, premolar; *m*, molar. (After *Flower*.)

marked *b*, and bears eloquent testimony to the unity of structure underlying all mammals, and their probable descent from some generalized type. Thus we see that the horse walks on one finger only and that the hoof is simply the middle finger-nail (Fig. 169).

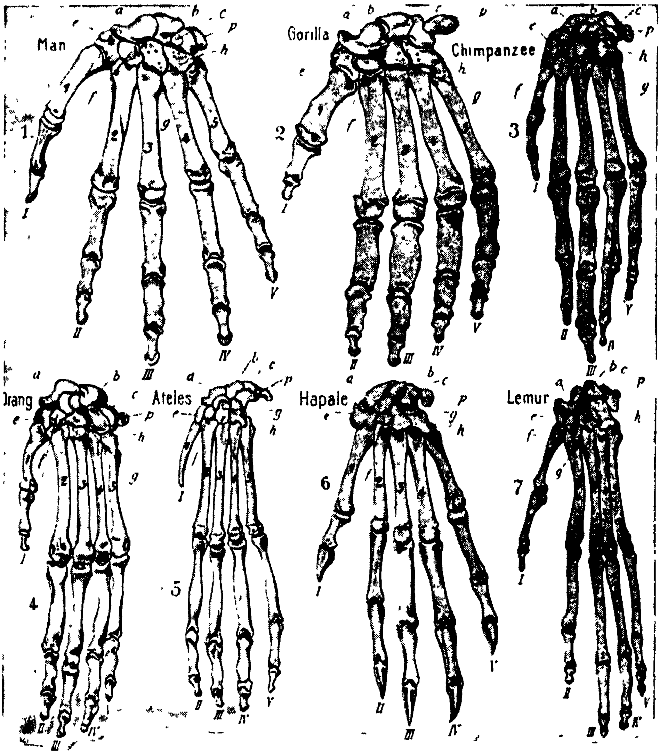


FIG. 171.—A Group of Hands.

Fig. 170 teaches us how two skulls, though widely different in appearance, yet contain all the essential parts in common. It shows that the great difference in the human skull is due to the large increase in brain development.

We must now compare man with some nearer relations —the Primates.

The numbers and letters in Fig. 171 correspond to the same parts. The group of small bones at the top of each forms the wrist, or carpus; the long bones, numbered 1, 2, 3, 4, 5, support the palm; after these come the three jointed bones of the fingers and the two jointed ones of the thumb. To look at and count these

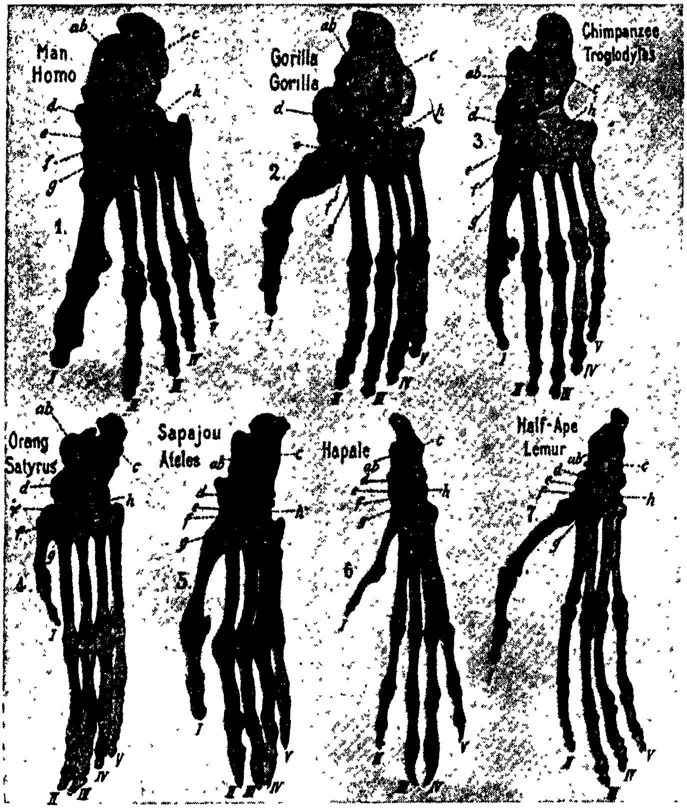


FIG. 172.—A Group of Feet.

bones is to be convinced that they are in origin identical. They furnish the strongest evidence that all the animals to which they belong should be placed in one group.

The most striking thing about the feet shown in Fig. 172 (here again the numbers and letters correspond to the same parts) is their great difference from the hands. The mass of bones at the top of each is the ankle-joint or tarsus, and corresponds, in relationship, with the bones at the wrist-joint; but in the wrist there are eight bones, while in the ankle there are seven, for the large heel-bone or *Calcaneus* is really two bones that have become "fused" together and which correspond to the *Scaphoid* and *Lunate* bones in the wrist. Before the recognition of evolution men were classified as *Bimana* (two-handed) and the apes as *Quadrumana* (four-handed), but we now know that such differentiation was wrong, for both men and apes have two hands and two feet.

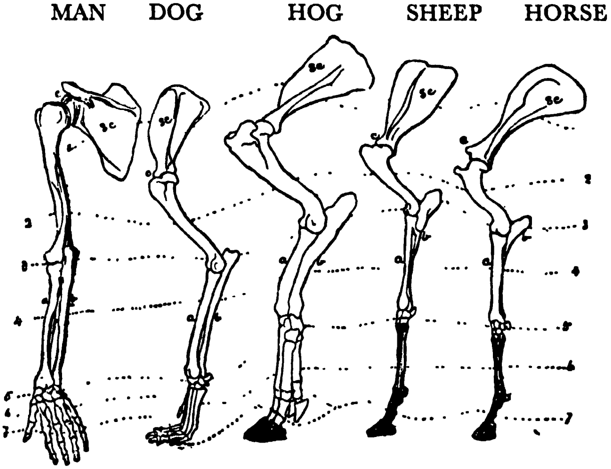


FIG. 173.—A Series of Fore Limbs. *Sc*, shoulder blade; *c*, coracoid process; *a*, *b*, bones of fore-arm; line 3 passes through the elbow joint; 5, through the wrist; 6, through the bones of the hand; 7, through bones of the fingers.

The most striking difference is seen in the big toe. In man it lies almost parallel with the other toes; but in the gorilla it is bowed out, so that it is opposable—*i.e.* it can be pressed against the adjoining toe for grasping. (This arrangement is found in the human embryo, and may still be seen in a very young child after birth.) It was this use of the toe in grasping which gave to the apes the description *quadrumana*.

In the case of the fore limbs of these quadrupedal animals (Fig. 173) no one can doubt that they are all made on the same plan. Their differences are chiefly differences of arrangement, and, though in some cases bones have disappeared, in no instance do any *additional* bones appear.

As in the fore limbs, the similarity in the arrangement of the hind limbs (Fig. 174) is most striking. The dotted line 5 passes through the ankle-joint in each case. Man and ape are *plantigrade*, which means, as we saw above, that the whole foot is placed on the ground, while the dog, sheep and horse are *digitigrade*, that is, they walk on their fingers.

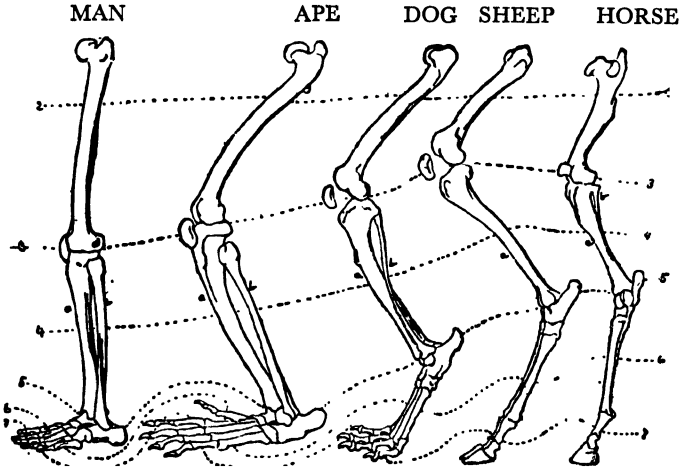


FIG. 174.—A Series of Hind Limbs. The top is the hip-joint; line 2 passes through the femur or thigh-bone; 3, through the knee; 4, through bones of leg; 5, through the ankle; 6, through bones of the foot; 7, through bones of toes.

In the case of man, with the upright position given him by thousands of years of practice, the leg stands almost perpendicularly over the foot. Both hind and fore limbs have obviously a similarity of plan. The thigh-bone, or femur, corresponds to the shoulder-bone, or humerus, the two shank-bones (tibia and fibula) to the two arm-bones (radius and ulna), the ankle-bones (tarsals) to the wrist-bones (carpals), the foot-bones (metatarsals) to the hand-bones (metacarpals), and, lastly, each toe-bone corresponds to a finger-bone. The wonderful modifications in these structurally similar limbs point emphatically to a common ancestral group as their one origin, which, as we have seen, was the five-toed, roof-headed Amphibians (Stegocephala).

The fore limb of the whale looks like a paddle and is used as such, but underneath the skin we find it has a real hand and arm which bear a striking resemblance to those of man (Fig. 175).

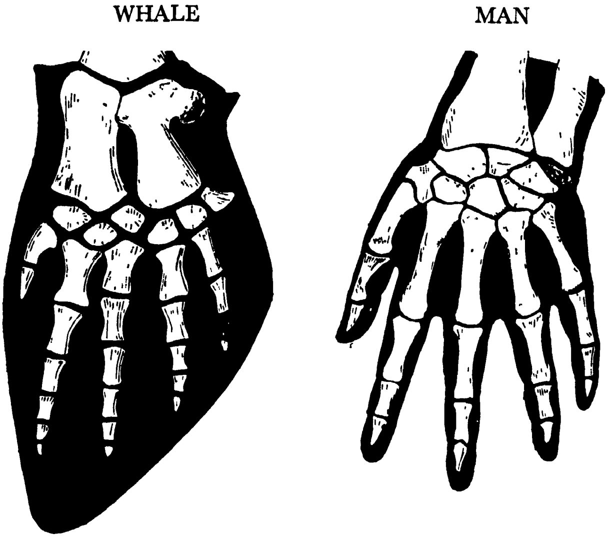


Fig. 175.—Paddle of a Whale and Hand of Man.

There are few better ways of learning evolution than that of examining some one organ in its various modifications and adaptations.

Limbs were first evolved in the earliest shark-like fishes (*Selachii*). From these they have been inherited by all the higher vertebrates—first as polydactyle *fins*, afterwards as pentadactyle hands and feet. The breast-fin or fore limb was originally just the same in structure as the belly-fin or hind limb. The primitive form of the limbs, as found in these earliest fishes, is still to be seen in the Australian dipneust—the Ceratodus, or Burnett salmon—(Fig. 97) whose paired fins are flat, oval paddles supported by a biserial cartilaginous skeleton (Fig. 176, I).

The broad breast-fin of our shark-like or Selachian ancestors lost all the radii on one side and many, but not all, of those on the other. The fin-stem became the arm, and the remaining radii the "hand" of the terrestrial vertebrate (Fig. 176, II, III).

Careful comparison of the fore limb of Ceratodus, the

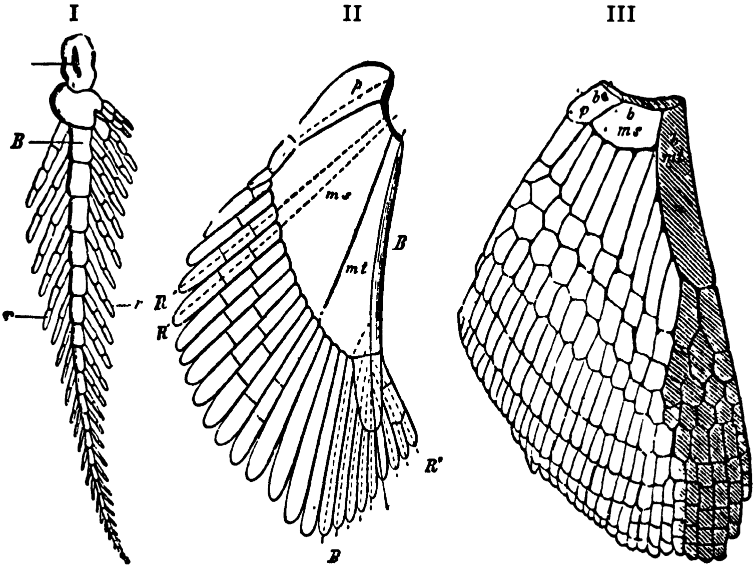


FIG. 176.—Three Breast-fins. I: Skeleton of the breast-fin of the dipneust, Ceratodus; A, B, cartilaginous series of the fin-stem; *r*, *r*, cartilaginous fin-radii. II: Breast-fin of early shark. The radii of the median fin-border (B) have nearly all disappeared; a few only (R′) are left; R, R, radii of the lateral fin-border; *mt*, metapterygium; *ms*, mesopterygium; *p*, propterygium. III: Breast-fin of a young shark. The radii of the median fin-border have wholly disappeared. The shaded part on the right is the section that persists in the five-fingered hand of the higher vertebrates; *b*, the three basal pieces of the fin; *mt*, *ms*, *p*, same as in II; *mt* is the rudiment of the humerus. (*Gegenbaur.*)

shark (Fig. 176), the Amphibian, gorilla, and man (Fig. 177) will furnish you with a good idea of how the limbs of animals arose from the fins of fish.

At about the end of the sixth week the human embryo is roughly half an inch long, has a well-marked tail, and *webbed* limbs. These first appear as "limb-buds," which are outgrowths, not, as was formerly thought, of the vertebral system but of a membrane called the *Somatopleure* that envelops the whole body; they are, in fact, a specialized portion of a continuous lateral fin-ray fold. This fold ultimately disappeared except at four sites where pieces of it remained as the paired pectoral and pelvic fins of the fish, and these, in their turn, became later modified into the arms and legs of terrestrial vertebrates.

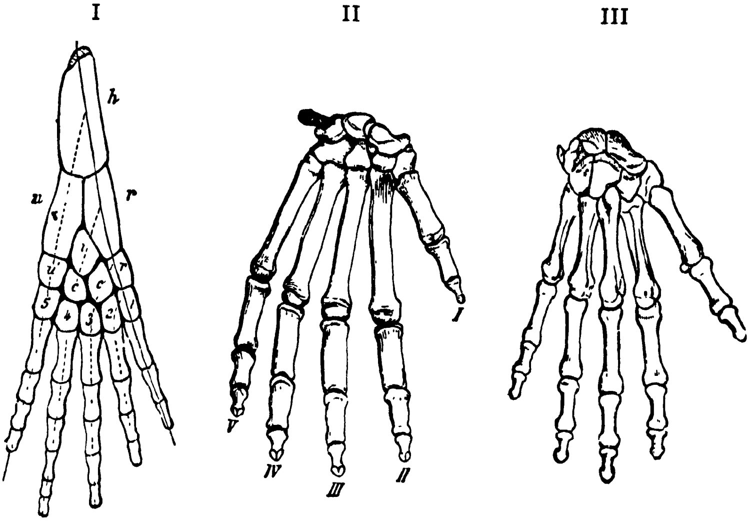


Fig. 177.—Three Skeletons of Right Hands, seen from the back. I: Fore leg of Amphibian. *h*, upper arm (humerus); *r*, *u*, lower arm (*r*, radius; *u*, ulna); *r*, *c*, *i*, *c*, *u*, wrist-bones of first series (*r*, radiale; *i*, intermedium; *c*, centrale; *u*, ulnare); 1, 2, 3, 4, 5, wrist-bones of the second series (*Gegenbaur*). II: Gorilla's hand. III: Human hand.

Man has many structures known as "rudiments" or "vestiges" which are no longer of any use to him. The ears in Fig. 178 show remarkable points of similarity; for instance, that of the human fœtus closely resembles that of the orang, while the two ears at the bottom left hand of the figure show ape-like features in the small lobes and pointed margins. It will be remembered that the whole of the shell (*pinna*) of the ear in man is the useless vestige of a once very mobile organ.

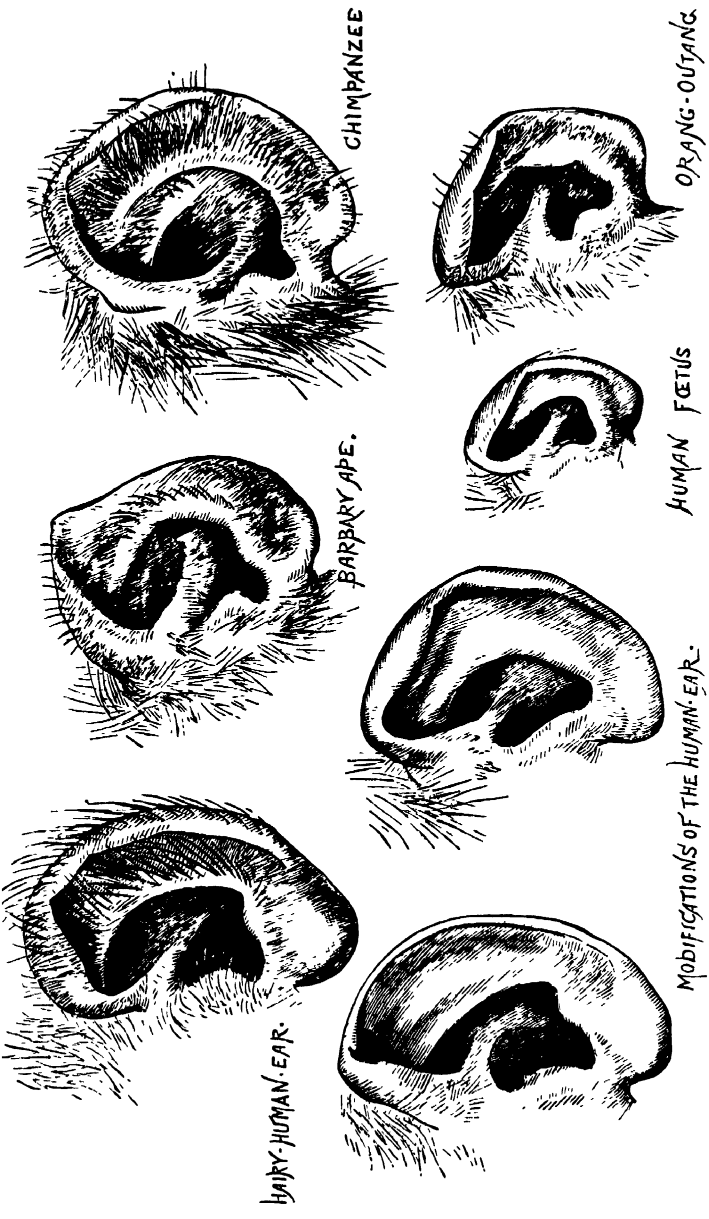

CHIMPANZEE
ORANG-OUTANG
BARBARY APE.
HUMAN FŒTUS
MODIFICATIONS OF THE HUMAN EAR.
HAIRY-HUMAN-EAR.

Fig. 178.—A Group of Ears.

The photograph of a fœtal orang shows a much earlier stage of the pointed ear (Fig. 179). Alongside it is shown a human ear with the very interesting point, marked *a*, known as the Darwinian tubercle. It is more in evidence at birth than in later life, and in men than in women, and is the relic of the turned-over pointed tip of the common ancestor of man and ape.

Grown-up man presents rudimentary hair over most parts of the body. In the case of the arms it is peculiar, for the hair on both the upper and lower arm is directed *to* the elbow. This curious disposition of the hair is a feature common to man and the apes (Fig. 180), and has been brought about through the habit of simians when sitting in the rain of placing their hands above the head. As observed by Wallace, the upper limbs are thus made to act as a thatch to throw the water clear of the body. The direction of the hair tracts generally on the human body constitutes remarkable evidence of descent from hirsute arboreal ancestors.

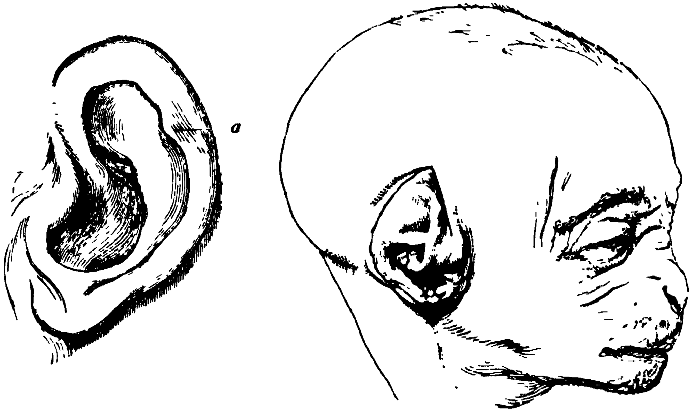


Fig. 179.—Human Ear and Fœtus of Orang.

We will next look at the comparative anatomy of the inside of the ear. The general arrangement is shown in Fig. 181. The origin of the little bones inside the ear is only explicable in terms of evolution. They are named, from their shape, the *Malleus* or hammer, the *Incus* or

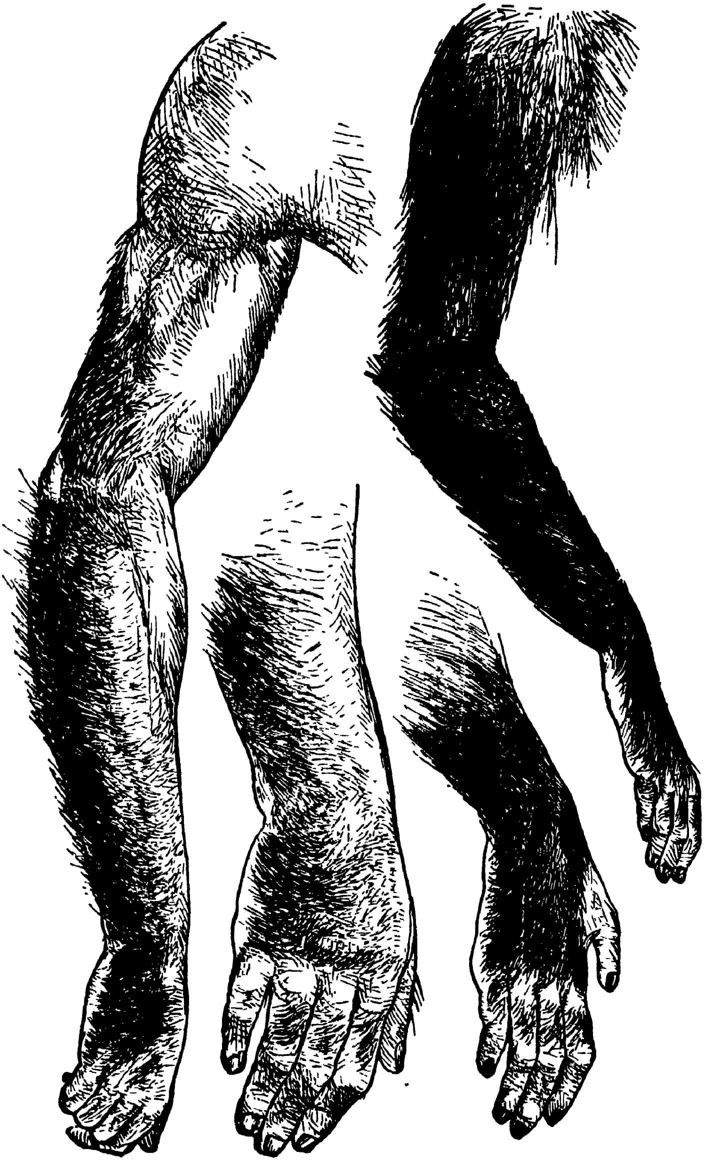


FIG. 180.—Hair Tracts on Arms.
Left: Man. Right: Male Chimpanzee.

anvil and the *Stapes* or stirrup bone. They are in reality the discarded remains of the old gill-arches put to new uses; the hammer and anvil being parts of the first gill-arch, the stirrup of the second. These bones, the tiniest in the body, have had a more chequered career than perhaps any other part of the skeleton, yet their position is so sheltered from the storm and stress of an ever-changing environment that they have preserved throughout the ages a most remarkable similarity in widely different groups of animals (Figs. 182 to 185). The hammer-anvil joint was formerly the jaw-joint of

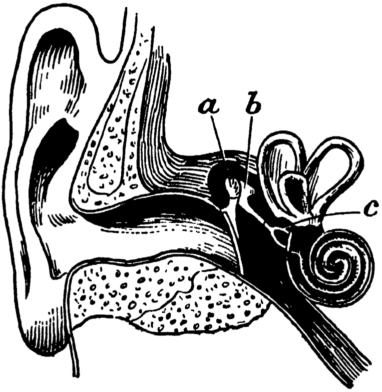


Fig. 181.—Diagrammatic Scheme of the Ear. (*a*) Malleus, (*b*) Incus, (*c*) Stapes.

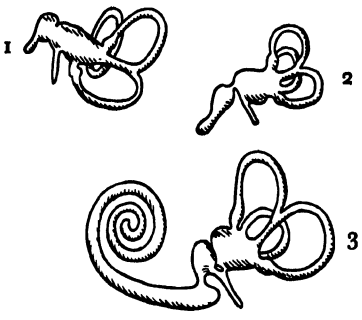


Fig. 182.—Diagrams of Auditory Labyrinth. (1) Fish, (2) Bird, (3) Mammal and Man.

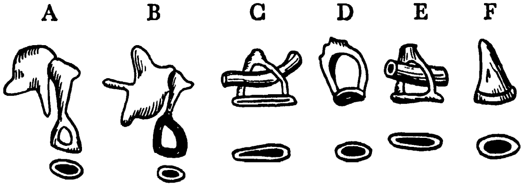


Fig. 183.—Earbones of: A, Bat; B, Shrew. Stirrup bone of: C, Mole; D, Hedgehog; E, Marmot; F, Sloth. The discs below indicate the shape of the foot of the stirrup. An artery is shown passing through the stirrup bone of the mole and marmot.

the shark-like fishes, while in the still more remote past these bones formed a part of the gills used in breathing.

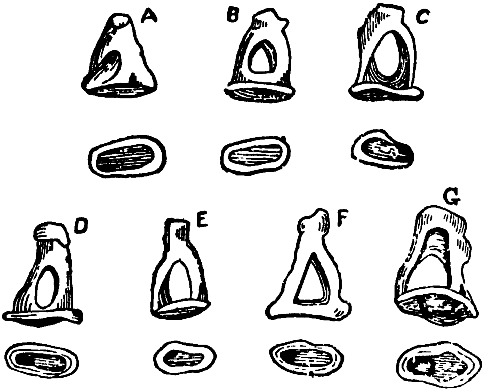


FIG. 184.—Stirrup bone of Ungulate Mammals. A, Hippopotamus; B, Hog; C, Musk-ox; D, Horse; E, Tapir; F, Rhinoceros; G, Elephant.

Fig. 186 is the view we should have if we took a brain out of the skull and turned it over. In the central part may be seen the cut ends of the spinal cord and nerves that connected the organ with the rest of the body.

Fig. 187 shows the brain as it appears from the side. It rises from a stalk where the spinal cord joins the brain. The horizontally-shaded mass completely covered by the hinder part of the cerebrum is called the "little brain" or cerebellum.

Fig. 188 is a view of the inner aspect of the right hemisphere. The curved area marked CC is the *corpus callosum* or great commissure, that joins the two hemispheres together.

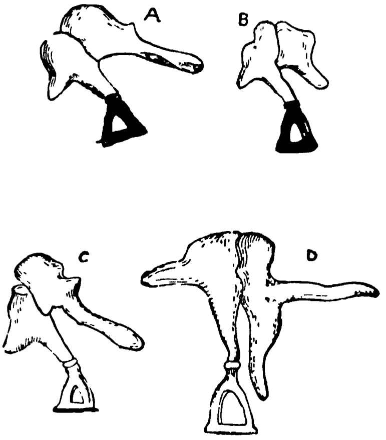


FIG. 185.—Ear-bones of Monkeys compared with those of Man. A, Lemur; B, Cebus (a platyrrhine monkey); C, Cercopithecus (a catarrhine monkey); D, Man.

Figs. 189 and 190 tell their own story. Note that in all the Primates (E—M) the cerebral hemispheres cover the cerebellum; in lower mammals (A, B, C, D) the little brain is not so covered.

Observe also in the brain (Fig. 191, I) of that very primitive mammal the duck-mole (Fig. 119) how smooth it is, and the relatively large size of the "smell-centre" (*olf*) and its uncovered cerebellum (*cbl*). The brain of the kangaroo (Fig. 191, II), while smoother than that of man, is more convoluted than the duck-mole's. The cerebral fissures, so characteristic of human beings, are beginning to appear. The brain of the human fœtus (Fig. 192, B) is also, as we should expect, smooth. Above it is shown the brain of an *adult* Midas, one of the flat-nosed South American monkeys, and it will be seen that each presents the same well-marked Sylvian fissure.

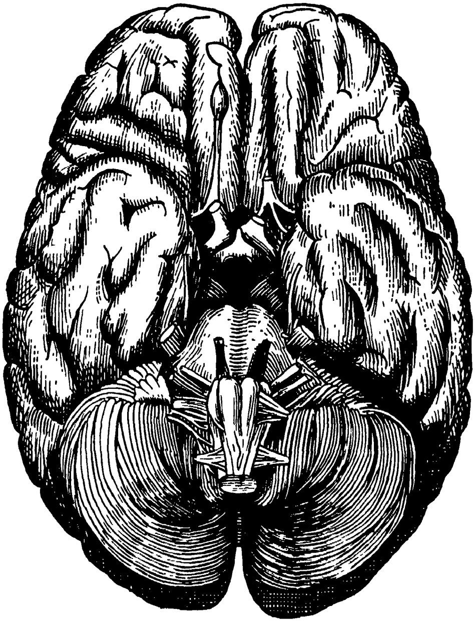


FIG. 186.—Human Brain from beneath.

The comparative series of brains given in Fig. 193 shows progressive consolidation and enlargement as one passes up the animal scale.

I is the brain of the fish; the cerebellum *cb* is fully

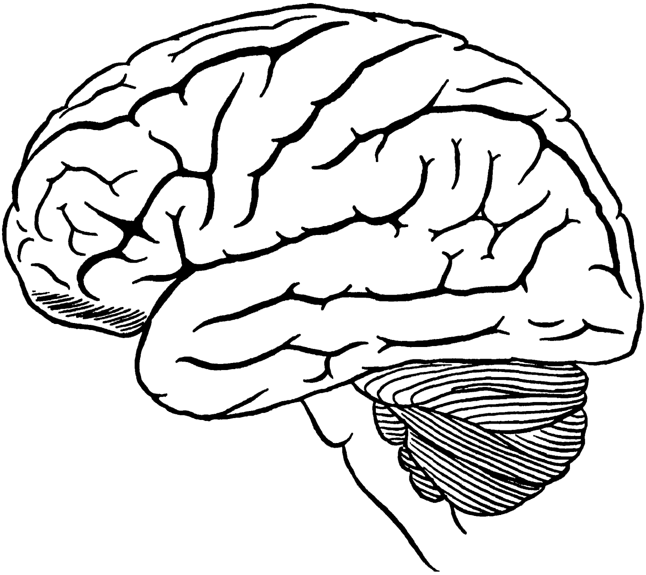


FIG. 187.—Left Hemisphere of Human Brain, outer aspect.

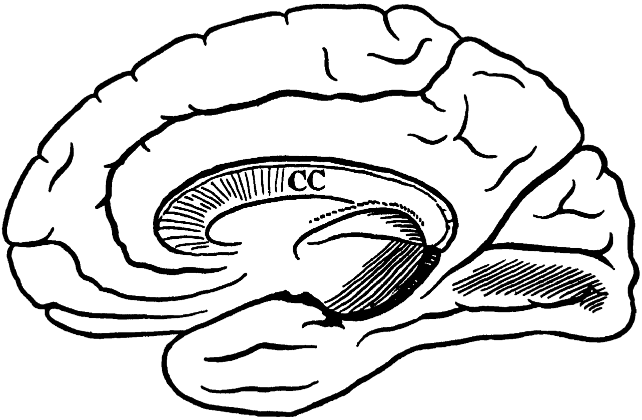


FIG. 188.—Inner aspect of the Right Hemisphere of Human Brain, showing the great nerve-band or *corpus callosum*, CC, that links up the two hemispheres.

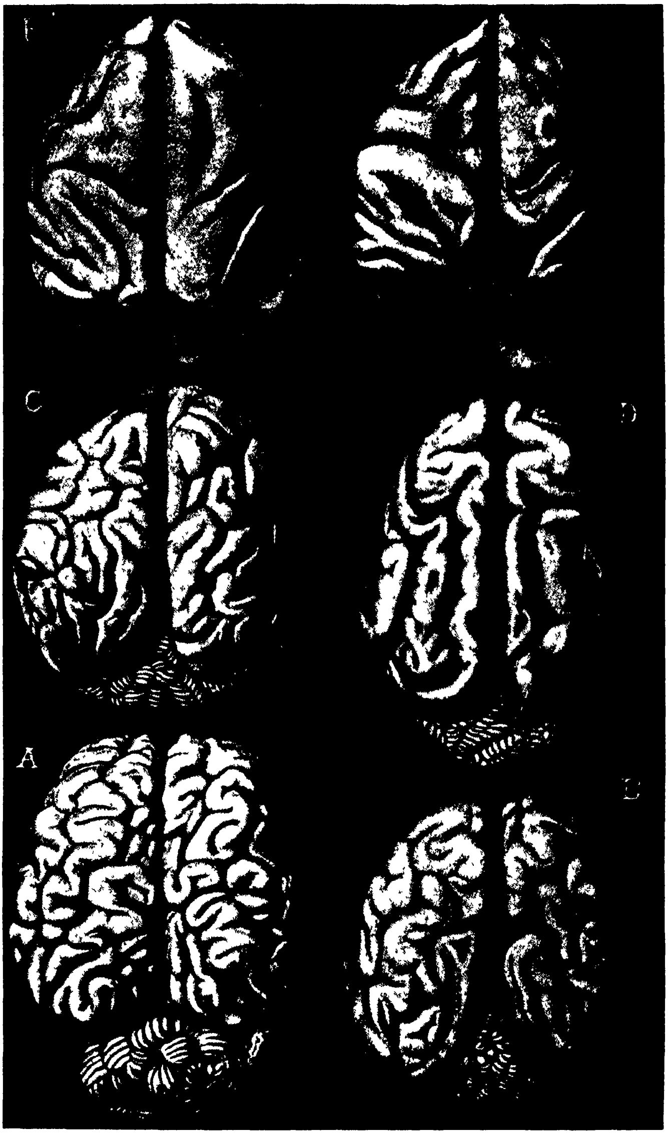


FIG. 189.—Six Mammal Brains. A, giraffe; B, seal; C, dolphin; D, lion; E, Semnopithecus (ape); F, Cercopithecus (monkey).

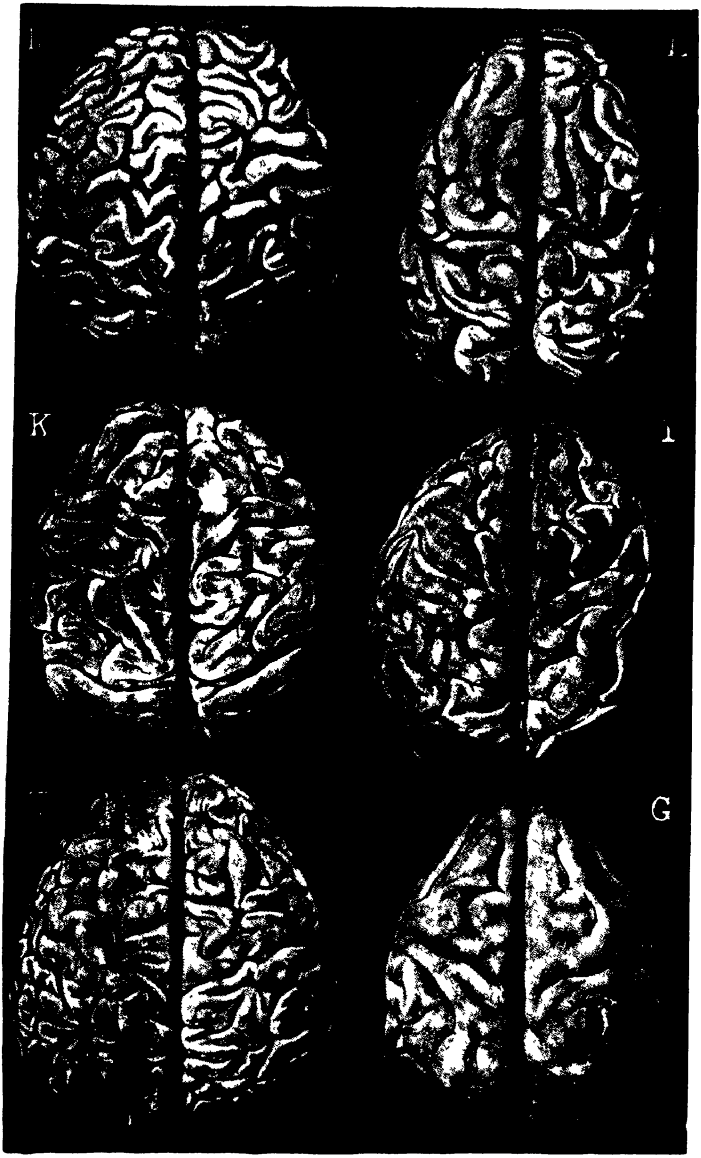


Fig. 190.—Six Brains of Apes and Men. G, gibbon; H, chimpanzee; I, orang; K, gorilla; L, Bushman; M, civilized man.

exposed, while the olfactory lobes *ol* are relatively very highly developed.

The optic lobes *op* are connected with the eyes and subserve vision. Without this connection we should not be able to see.

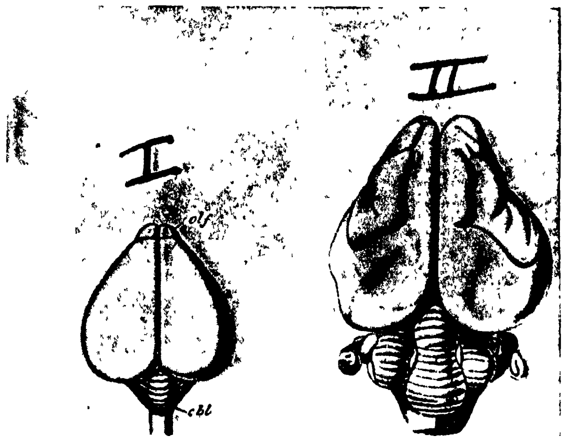


FIG. 191.—Brains of the Duck-mole and Kangaroo. I, brain of the Duck-mole (Ornithorhyncus), dorsal view, natural size; *cbl*, cerebellum; *olf*, olfactory lobes. II, kangaroo (Macropus). (After *Owen.*)

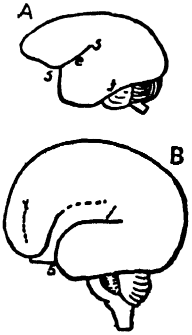


FIG. 192. — External surface of the left hemisphere of (A) Midas, (B) human fœtus (five months).

Fig. 195 shows three early stages of chicken brains, and helps us to understand how our organ of thought begins. In I we observe that the spinal cord, which runs nearly the whole length of the body, expands into a bulge at the top, just as it does in the Ascidian and Amphioxus (see Fig. 88).

In II it has divided into three round bodies, the fore-, mid- and hind-brain; this is the *permanent* stage of some of the lower fishes.

In III the appearance of an intermediate- and after-brain brings the number of these small bodies up to five, which as we have just seen is the number of brain-parts in the higher fishes. The brain of a chicken or of a man passes through similar stages to those passed through by the Ascidian, Amphioxus, and fishes! In Fig. 196 the

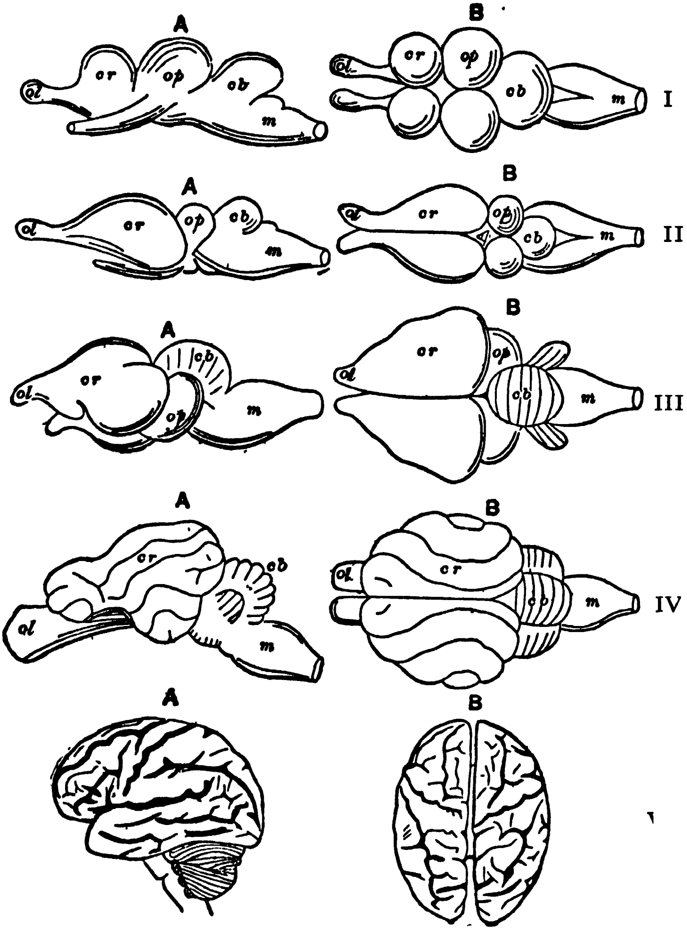


FIG. 193.—Comparative Series of Brains. A, side-view; B, seen from above. I, fish; II, reptile; III, bird; IV, mammal; V, man. *m*, medulla; *cb*, cerebellum; *op*, optic lobes; *cr*, cerebrum; *ol*, olfactory lobes.

development of the embryo chick's brain is carried a step farther.

Notwithstanding the overwhelming evidence of the evolution of the human brain and its remarkable resem-

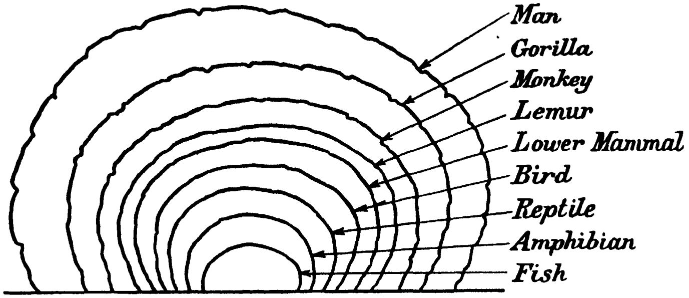


FIG. 194.—Schema to illustrate relative sizes of Brain in different classes of Vertebrates.

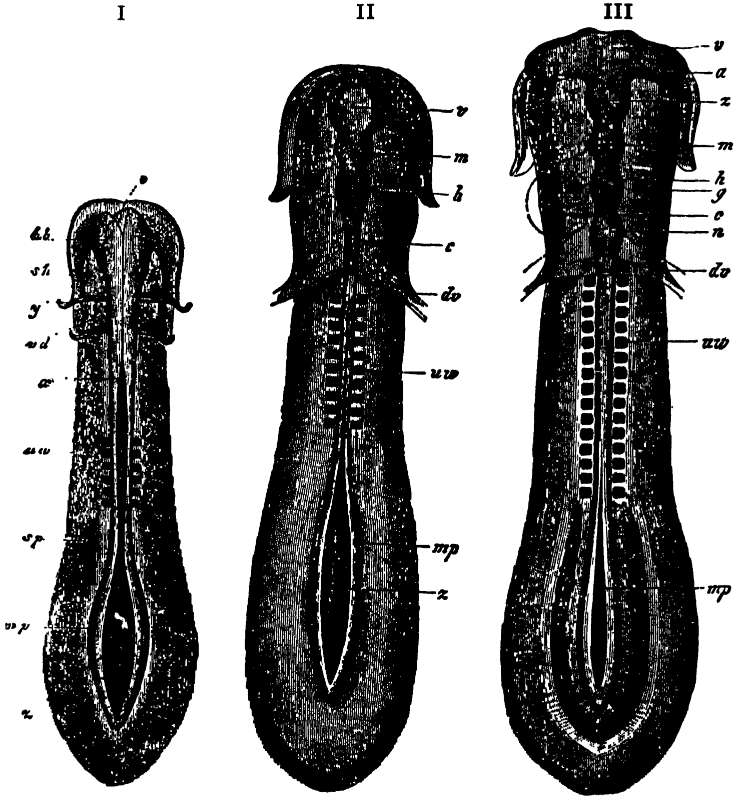


FIG. 195.—Three Embryonic Chickens in three successive stages of development, dorsal view, magnified about twenty times. I, brain a simple vesicle (*hb*). Medullary furrow still wide open from *x*; much enlarged behind at *z*. II, brain divided into three vesicles: *v*, fore brain; *m*, middle brain; *h*, hind brain. III, brain divided into five vesicles: *v*, fore brain; *z*, intermediate; *m*, middle; *h*, hind; *n*, after brain; *o*, optic vesicles.

blance to that of the higher ape, the Special-Creationists persisted in saying: " It is only an outside resemblance. Cut into it, and you will find most important points o difference." So Huxley dissected the brains of apes[1]

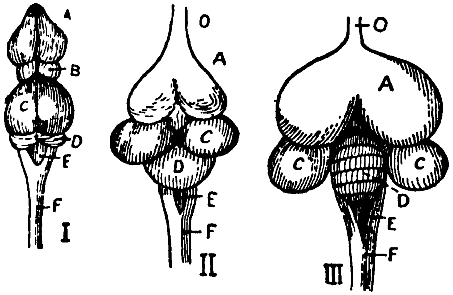


FIG. 196.—Brains of Embryo Chicks. I, 8 days; II, 16 days; III, 20 days. Letters same in all—O, olfactory lobes; A, hemispheres of the brain; B, optic thalamus; C, optic lobes (corpora bigemina); D, cerebellum; E, fourth ventricle; F, spinal cord.

to see. It had been seriously maintained by certai skilled anatomists that the ape had no posterior lobe (Fig. 197) (*a*), nor posterior cornu (horn) (*c*), nor hippocampus minor (*x*). Huxley, and independently Si William Flower, showed them to be among the mos

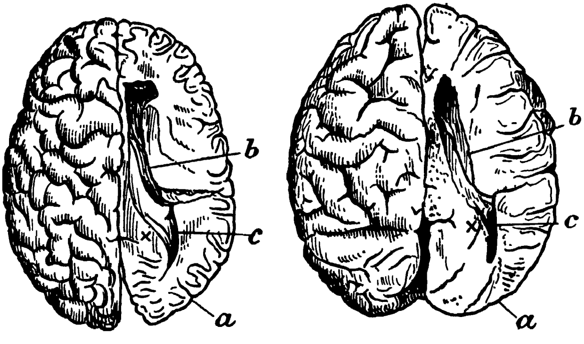


FIG. 197.—Cerebral Hemispheres of Man and Chimpanzee dissected *a*, Posterior lobe; *b*, lateral ventricle; *c*, posterior cornu; *x*, hippocampu minor.

---

[1] Huxley's published researches on this question were: 1, Zoologica Relations of Man and the Lower Animals; 2, On the Brain of the *Atele Paniscus*; 3, On Nyctipithecus.

constant parts of the ape's brain, and always in the same position as in the brain of man! But even after the demonstrated existence in the brain of the ape of what had hitherto been claimed to be specifically human structures, there were still people who refused squarely to face the evidence and continued to deny Huxley's findings.

No biologist denies that the brain of man is a more highly developed organ than that of apes, but " in the brain," as Huxley said, " man differs *less* from the chimpanzee or the orang than these do from monkeys, and the difference between the brains of the chimpanzee and of man is almost insignificant when compared with the difference between the chimpanzee brain and that of a lemur."

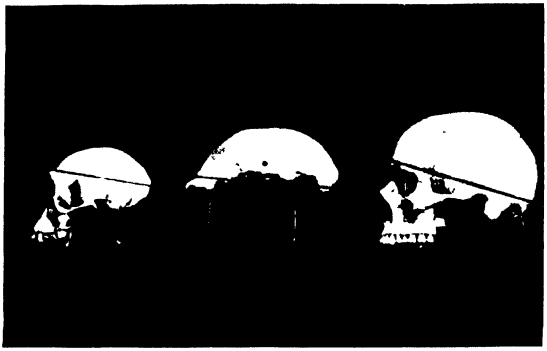


FIG. 198.—Comparison of the Tops of Skulls.

Professor Elliot Smith and Sir Arthur Keith—leading modern authorities in comparative anatomy—are agreed that there is no part of the human brain that is not present in that of the simian. " No structure found in the brain of an ape," says the former of these two scientists, " is lacking in the human brain; and, on the other hand, the human brain reveals no formation *of any sort* that is not present in the brain of the gorilla or chimpanzee. . . . The only distinctive feature of the human brain is a quantitative one." Not only man's brain, but his bones, muscles, nerves, and blood-vessels—in fact, all his organs—are almost exact replicas of the corresponding parts in the ape.

Fig. 198 shows the tops of three skulls photographed by

Sir Ray Lankester. On the left is the skull of a chim panzee, in the middle the skull of the " ape-man " Pithec anthropus, on the right the skull of a modern man. Th line (which goes through corresponding points in eac of the three skulls) shows how much shallower is th dome of the ape's skull than that of man, while th middle skull (Pithecanthropus) exhibits a shallowness tha is a mean of the other two. (See also Fig. 194.)

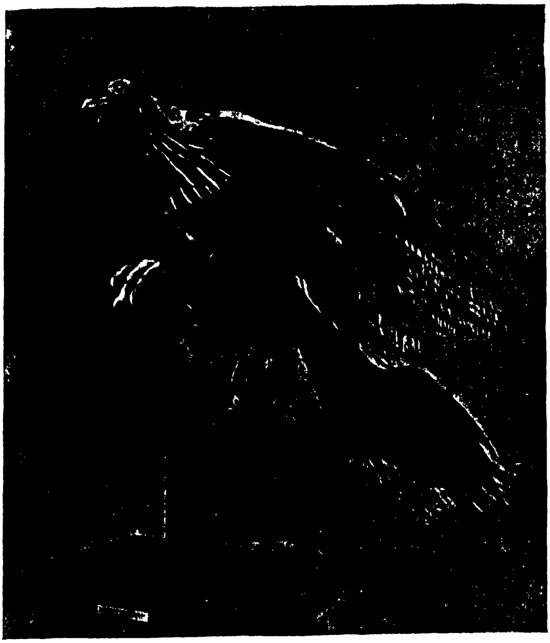


Fig. 199.—The Stinking Pheasant or Hoatzin. (Opisthocomus cristatus).

We may close this chapter with a reference to a ver remarkable bird that one might almost describe as a sti living reptile-bird. The crested Hoatzin (Fig. 199) c Stinking Pheasant, as it is called, on account of the stron musk-like odour given off by the adults, haunts the dens thickets bordering the lagoons, creeks, and rivers of th Amazon valley.

Mr. Pycraft, the great authority on birds, says: " I the wing of this nestling (Fig. 200) we have a revelatio of profound importance, for, so it seems to me, through it we get a glimpse into the phylogeny, not only of its immediate allies (the *Gallinæ*), common fowls, but possibly into that of the whole class of birds."

The Hoatzin lives in trees, rarely, if ever, coming to the ground, and its call is a reptile-like hiss. Its young can see, swim, and climb about as soon as hatched. In climbing the young not only use their beaks in parrot-like fashion and their large feet for grasping, but they also use their wings as hands for holding on to branches. They are able to do this by means of two clawed finger-tips that protrude from each wing. So when Cuvier declared that birds were really four-legged animals he was quite correct so far as the young Hoatzin is concerned. As the bird grows, its claws disappear, while its feathers—specially arrested in growth during early life so as not to impede climbing—come to perfection, and the bird gets its full wings and is able to fly. Here, then, in the American forests, we can see a truly living fossil, a creature that begins life in a clumsy, four-footed reptile-like manner and ends by flying about as a bird!

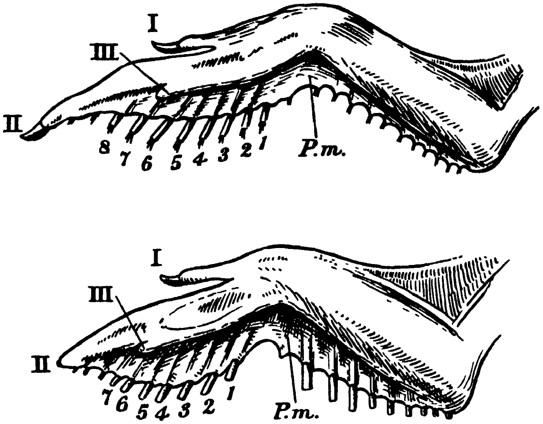


FIG. 200.—Right Wing of a young Hoatzin, showing how the second digit (II) is produced beyond the *ala membrana* (*P.m.*), and that the development of remiges 8–10 has been arrested, so as not to interfere with the freedom of the long finger when climbing. (Below) Right wing of nestling of Common Fowl. Owing to the exchange of an arboreal for a terrestrial habit, the manus is gradually shortening. The pollex only retains the claw. The second digit projects but slightly beyond the *ala membrana*, but the development of the most distal remiges is still arrested.

CHAPTER NINE: EMBRYOLOGY AND RUDIMENTS

WE have seen from the evidence of astronomy that evolution is not necessarily confined to living things. Next we have learnt from geology that many species of animals have disappeared, while others have altered in form, and all are traceable back to one ancestral group; in fact, that, as the rocks themselves have evolved, so have the animals whose skeletons they preserved. The further back we go into the history of the past, the less are the ancient animals like our modern ones; and the older the skulls of men, the more simian-like they are.

Zoology shows us how impossible it is to draw a sharp line between one group of animals and another. In the last chapter we saw agreements of plan or structure explicable only on the supposition that all animals have come by a long series of changes from some common ancestor.

There is stronger positive evidence of evolution in embryology than elsewhere. (Embryology is the science which traces the growth of any animal, *before birth*, from a cell, about 120th of an inch in diameter, to its relatively complete form when it is born.) Such difficulties meet us when we consider rudimentary structures that no explanation can possibly be given of them except that furnished by evolution, but until young people are made familiar with the methods of science, it will be a hard task to teach the older ones anything about embryology, since it deals with structures that can be seen only through a microscope.

Embryology furnishes us with a record of animal forms and of the marvellous likenesses existing between them. Every animal, from the lowest up to man, contributes its page of the revelation of the past. The largest and smallest, most hideous and most beautiful, the stupidest and wisest, all start life as a tiny cell and, for a longer or shorter period, pass through practically indistinguishable stages.

It is no matter of imagination; here we are face to face with the ever-recurring fact of our own growth from a single tiny cell, for each one of us was once a protozoon. "The greatest of men—" writes Dr. Saleeby, "your

Aristotle or Shakespeare—began his individual career as a unicellular organism just visible, in a good light, to the naked eye. This minute creature has neither organs, nor parts, nor passions, nor ideas. Yet in nine months it becomes a baby, and twenty-seven years later it may write a *Romeo and Juliet*, or be founding a new religion. Had we seen for ourselves the æonian evolution of man from the primitive slime, but never witnessed the relatively instantaneous development of a man from a human germ, we might well account the latter impossible. But, having seen the greater marvel, we cannot call the lesser incredible.”

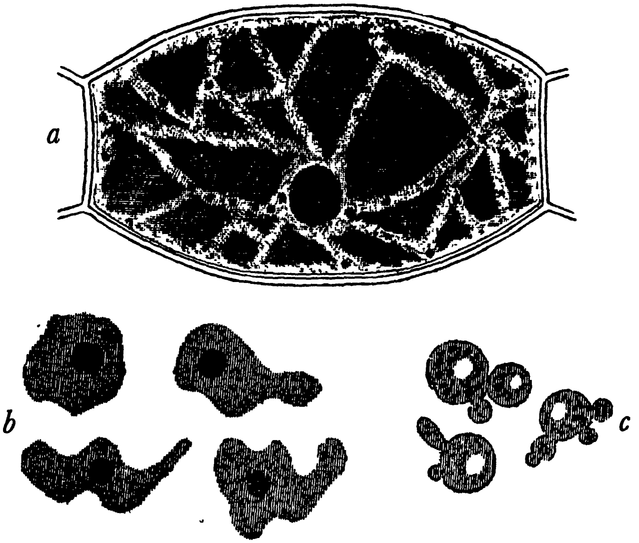


FIG. 201.—*a*, Cell from filament of *Tradescantia*. The protoplasmic threads are light, and in them are contained the nucleus and chlorophyll granules. The spaces between the threads are filled by coloured cell-sap. *b*, A white or amœboid corpuscle from the blood of a frog, showing changes of shape undergone during five minutes. *c*, Group of yeast cells, exhibiting active budding.

The better to understand some of these living wonders we will begin with a study of a few of the lowest forms of life.

Fig. 201 shows the boundary wall, the thin threads of protoplasm and the nucleus that go to the make-up of a single hair-cell of *Tradescantia*, the Virginian spider-wort. The bodies at *b* are blood cells and they look and behave just like amœbæ. Protoplasm is the living part of the cells of all animals and plants; in general appearance it is not unlike the transparent portions of the jellyfish and frog-spawn. A complete division of a cell such as that of *Tradescantia* (Fig. 201, *a*) takes ninety minutes.

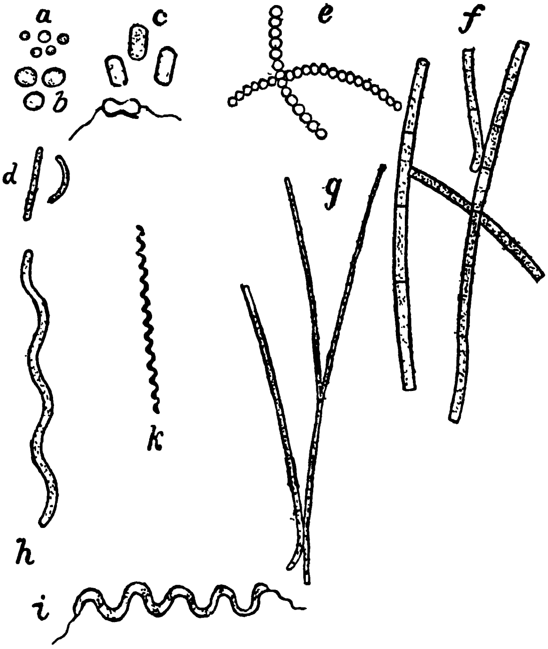


FIG. 202.—Forms of Bacteria. *a*, Micrococci; *b*, macrococci; *c*, bacteria; *d*, bacilli; *e*, streptococci; *f*, leptothrix; *g*, cladothrix; *h*, vibrio; , spirillum; *k*, spirochæte.

But the cells constituting the smallest known (visible) living individuals, the *Bacteria* (Fig. 202)—some of which are less than the one-ten-thousandth of an inch—divide into two individuals once every twenty minutes or so. A single Cholera bacillus, for example, becomes 2, 4, 8, 16, 32, 64 bacilli in two hours. Given unlimited food supply, room, and powers of spread, a single bacillus would in one day develop a progeny of 1,600 trillion descendants weighing a ton in weight. In two days their weight would far exceed that of the earth which, you may (or may not) remember, amounts to 60,000 million, million, million tons. In less than six months the whole visible universe would be solid with the protoplasm of the massed bacilli! Fortunately, such alarming geometrical rate of progression is checked, either by lack of food material or by the bacilli perishing as did the unfortunate human beings in the Black Hole of Calcutta, through accumulation of their own products of excretion. Bacteria exist almost everywhere if moisture and a favourable temperature of 32° F. to 160° F. are present. They soon swarm in millions in a single drop of organic fluid, such as blood, milk, urine, meat-juice, etc., if it is freely exposed to the air in which their spores float. Darken a room and allow a beam of sunlight to enter through a small aperture and you will see countless myriads of floating specks. Each speck is, so to speak, a Zeppelin, freighted with its minute invisible passengers—the bacteria spores. It is due to the agency of *micro-organisms*, as the bacteria and their fellow-microbes are called, that our edibles "go bad" and give off an evil smell, and, if swallowed, afflict us with "ptomaine poisoning." It is the "toxines" which these creatures manufacture and set free in our blood that give rise to the characteristics of such diseases as influenza, glanders, malaria, sleeping-sickness, and so forth. These highly specialized disease-producing "germs" or microbes have arisen by relatively rapid adaptation—indeed many of them are known to be far later products of evolution than man himself—from harmless *prototrophic*, that is, mineral-feeding, bacteria. Fortunately the beneficent types of microbes vastly outnumber the noxious kinds. Without the aid of bacteria the whole surface of the earth would soon be littered with the "corpses" of trees, flowers, elephants, mice, and men, for it is through their chemical handiwork that complex organic matter is returned into such simple compounds as water, carbon dioxide, nitrogen, free hydrogen, ammonia, marsh gas, and sulphuretted hydrogen—the end-products of lily or man. Without these end-products there could be none of that synthesis by plant protoplasm and sunlight whereby new life emerges. It is to the bacteria we owe the fertilization of our soil, the flavour of our wines and butters, and the ripening of our cheese; they make our vinegar, "cure" our

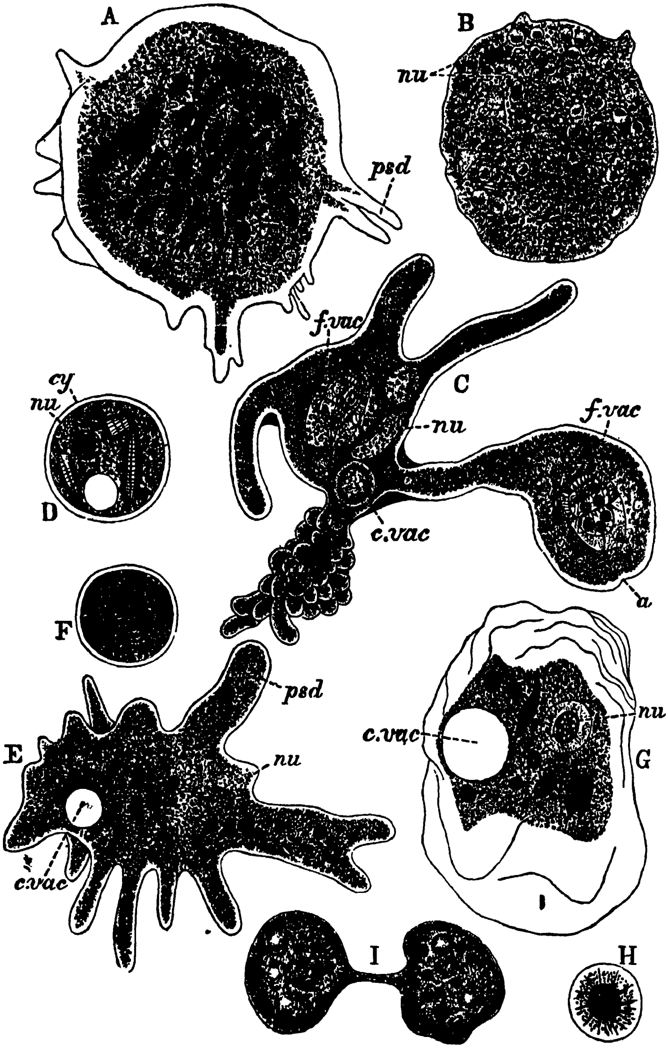


FIG. 203.—The Amœba. A, Amœba quarta, a living specimen, showing granular endosarc surrounded by clear ectosarc and several pseudopods (*psd*), some formed of ectosarc only, others containing a core of endosarc. The larger bodies are mostly food particles. This is enlarged 300 diameters. B, the same species killed and stained with carmine to show the numerous nuclei (*nu*). C, Amœba proteus, a living specimen, showing large irregular pseudopods, nucleus (*nu*), contractile vacuole (*c.vac*), and two food vacuoles (*f.vac*), each containing a small infusorium which has been taken as food.

The letter *a* to the right of the figure indicates the place where the protoplasm has united round the prey to enclose the food vacuole. D, an encysted Amœba showing cell-wall or cyst (*cy*), nucleus (*nu*), clear contractile vacuole, and three diatoms ingested as food. E, Amœba proteus, a living specimen, showing several large pseudopods (*psd*), single nucleus (*nu*), and contractile vacuole (*c.vac*), and numerous food particles. Enlarged 330 diameters. F, nucleus of the same after staining, showing deeply-stained granules of chromatin, surrounded by a distinct membrane. Enlarged 1,010 diameters. G, Amœba verrucosa, living specimen, showing wrinkled surface, nucleus (*nu*), large contractile vacuole (*c.vac*), and usual ingested organisms. Enlarged 330 diameters. H, Nucleus of the same, stained, showing chromatin aggregated in the centre to form a nucleolus. Enlarged 1,010 diameters. I, Amœba proteus, in the act of multiplying by binary fission. Enlarged 500 diameters. (From *E. J. Parker.*)

tobacco, sparkle our beer, tan our leather, prepare our indigo, enable our peas and beans to grow, and assist in the manufacture of our linen, jute, and hemp. So, while taking precautions to give the deadly microbes as wide a berth as possible by breathing fresh air, drinking pure beverages, and insisting on good sanitation and uncontaminated foods, let us ever remember that, as regards these invisible friends and foes, the net balance is on the credit side.

The Amœba (Fig. 203) is found in stagnant water. It seldom exceeds one-hundredth part of an inch, so is mostly invisible to the naked eye. It is a tiny shapeless blob of nearly colourless protoplasm. Amœba means the changing one, and it is so called because it is never the same shape for long together, for it is always pushing out some parts called pseudopods, *i.e.* false feet, at the same time drawing in others.

The Hæmatococcus, sometimes called Protococcus (Fig. 204), is found in standing rain-water that has turned a greenish-red colour. The colour is due to the presence of small organisms of which the Hæmatococcus is the commonest. Like the Amœba, it requires to be magnified some 900 times in order to be seen.

If this figure is compared with that of the Amœba, many points of resemblance will be seen; but the cell-wall of Amœba is probably nitrogenous, whereas this creature has its cell-wall formed of cellulose, a carbohydrate allied to starch, sugar, and gum. This indicates that whereas Amœba is near the bottom rung of the animal ladder, Protococcus is near the bottom rung of the plant ladder.

We should note that in Amœba locomotion is performed by any part of the body; in Hæmatococcus it is performed by a small part only—the flagella. We have here, therefore, the commencement of *specialization* manifesting itself as a *differentiation of structure and function*, or, in other words, a division of physiological labour.

The Springing Monad (Fig. 205) is partly plant, partly

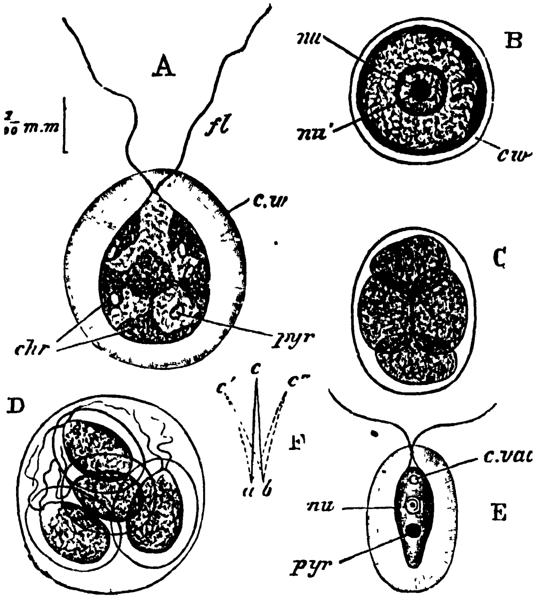


FIG. 204.—A, *Hæmatococcus Pluvialis*, mobile phase. Living specimen, showing protoplasm with chromatophores (*chr*), and pyrenoids (*pyr*), cell-wall (*c.w*), connected to cell-body by protoplasmic filaments, and flagella (*fl*). The scale of measurement to the left applies to Figs. A, B, C, D. B, resting stage of the same; C, the same, showing division of the cell-body into four daughter-cells; D, showing development of flagella before daughter-cells are liberated; E, *Hæmatococcus lacustris*.

animal, and is much smaller than Amœba or Hæmatococcus, being only $\frac{1}{3000}$th of an inch in length. It presents points of advance over these, however, for it has distinct ends, also a ventral and dorsal surface. It not only reproduces by simple fission like Amœba, but also by *conjugation* or *amphimixis* (both mixed), two organisms fusing into one (E^1 to E^5) and then later

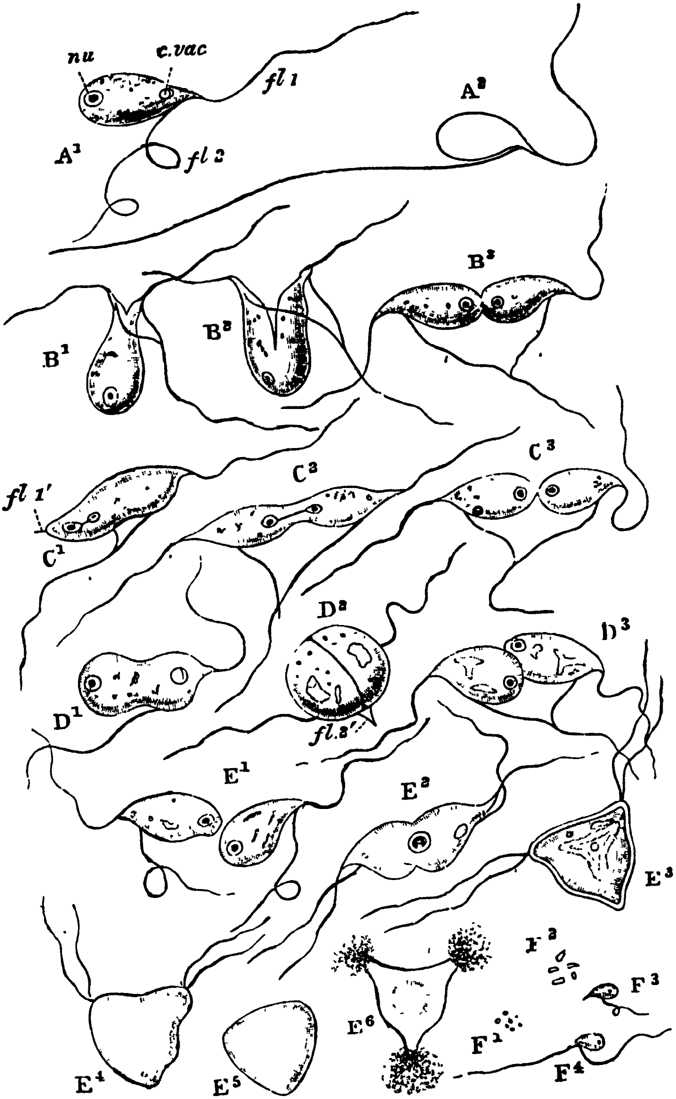


FIG. 205.—The Springing Monad, *Heteromita Rostrata.* A^1, living organism: *fl*^{2}, the coiled ventral flagellum by which the organism is anchored; A^2 shows the position at the forward limit of the spring, *fl*^{2} being fully extended; B^1–B^3, stages of fission, longitudinally, of the anchored form; C^1–C^3, stages of fission, transversely, of same; D^1–D^3, fission of the free swimming form; E^1, free swimming and anchored forms about to conjugate, till process is complete in E^5; E^6, the emission of spores; F^1–F^4, stages in the development of the spores. (After *Dallinger.*)

dividing into two (B^1 to B^3), or remaining as one and throwing off "spores" (E^6). During *amphimixis* the smaller and more active participant is probably the male, the larger and more passive, the female. Euglena (Fig. 206) is another plant-animal, for it feeds like a plant in the day and like an animal in the dark.

Fig. 207 exemplifies the varieties of form and phases among cells. In I and II (Fig. 208) we see the resting, passive, encysted phase; in III the explosive, reproductive phase with the begetting of daughter-cells, which at first are ciliated and extremely active, later sluggish and amœboid. Passive cells show conservative accumulation of material and energy and, physiologically, are anabolic. (*Anabolism* stands for functions subserving self-maintenance; it is individualistic, is constantly building itself up, and characterizes *femaleness.*) On the other hand, small active cells show radical and lavish expenditure of material and energy and, physiologically, are katabolic. (*Katabolism* stands for functions of species-maintenance; it is altruistic, is constantly breaking down its own substance, and is characteristic of *maleness.*) The female ova of plants and animals are preponderatingly anabolic, while the male sperm-cells are pre-

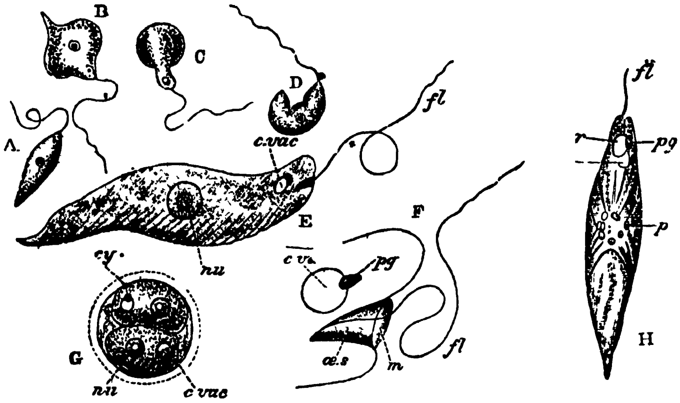


FIG. 206.—Euglena Viridis. A–D, living organisms, showing changes of form; E, enlarged view; F, enlarged view of *anterior* end, showing pigment spot (*pg*), mouth (*m*), gullet (*œs*); G, resting form after fission; H, active form. (From *Parker.*)

ponderatingly katabolic. The human female ovum or egg-cell is a spherical lump of protoplasm about the [illegible] of an inch in diameter, while the feverishly-active flagellated male cell is so tiny that thousands would be required to weigh down the female cell.

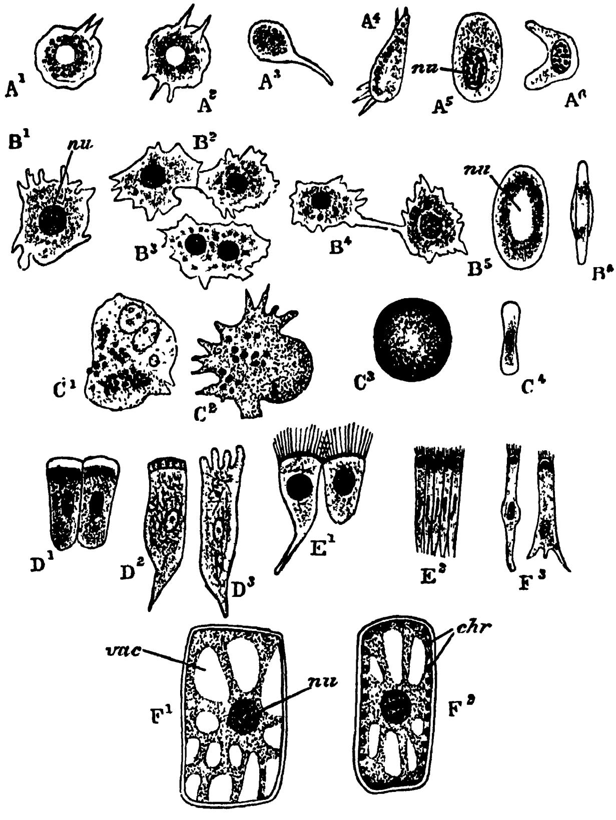


FIG. 207.—Typical Animal and Vegetable Cells. A^1–A^2, living leucocytes (blood corpuscles) of a crayfish. B^1–B^4, the same of a frog; B^5–B^6, surface view and edge view of a red corpuscle of frog; C^1, C^2, leucocytes of newt (the black dots are particles of vermilion which have been ingested); C^3, C^4, surface and edge view of red corpuscle of man; all D and E are epithelial cells from intestines or mouths of animals; F^1, cell from root of lily; F^2, from leaf of a bean. (From *Parker*.)

In Fig. 211 we see egg-cells from different animals, and it is only necessary to glance at them to see that the

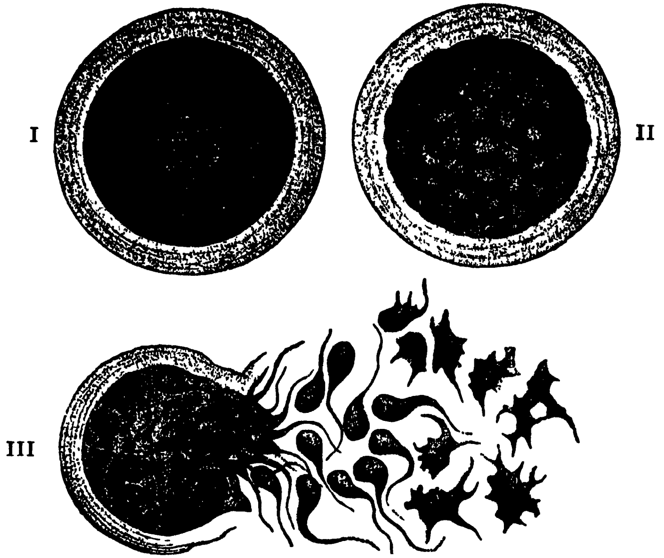


FIG. 208.—The Protomyxa, one of the primitive moulds, or Myxomycetes. I and II show it encysted: in II we see its division into numerous individuals within the cyst; III, the cyst bursts, the flagellate young rush out like so many minute tadpoles, but at once they become like Amœbæ, as seen on the right. (After *Geddes* and *Thomson*.)

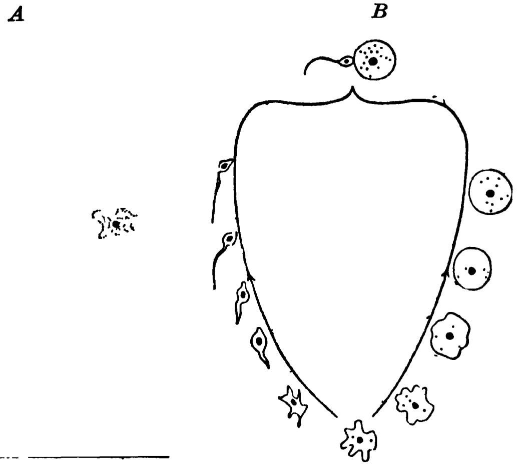


FIG. 209.—The Cell Cycle of Three Phases. *A*—E, encysted; C, ciliated; A, amœboid; I, II, and III are protozoa; IV, ovum and sperm of fern prothallus; V, animal cells; VI, a ciliated animal cell pathologically becoming amœboid; VII, sperm and amœboid sperm; VIII, amœboid and encysted ovum. (From *Geddes*.) *B*—Diagram showing how the ovum and spermatozoon gradually diverge from an undifferentiated amœboid type of cell, the one at the bottom.

general arrangement is the same. Any one of these egg-cells, if fertilized (and by this process, remember, is meant entry into the egg-cell of *one* male cell and the fusion of its nucleus with the egg-cell nucleus), becomes the beginning of a new being, be it a thistle, oak, sponge, worm, cat, or man. Fig. 212 shows the human ovum highly magnified. Its *actual* size is that of one of the smallest visible dots inside the little dark circle representing the nucleolus.

Within the nucleus of all animal and plant cells are certain very important constituents known as the *chromatin* *bodies*. It is they that hold and pass on, so to speak, the hereditary elements. When the parent-cell divides into two daughter-cells, the chromatin bodies, passing into these, carry with them the material basic entities that enable descendant cells to imitate and repeat the form, features, characters, and characteristics of former cell generations; they are, in a word, the *vehicles of heredity*. As a rule these chromatin bodies lie inside the nucleus as organized aggregations called *Chromosomes*. Both words are from the Greek *Chroma* (colour), because a feature of chromatin is its great avidity to take up dark aniline

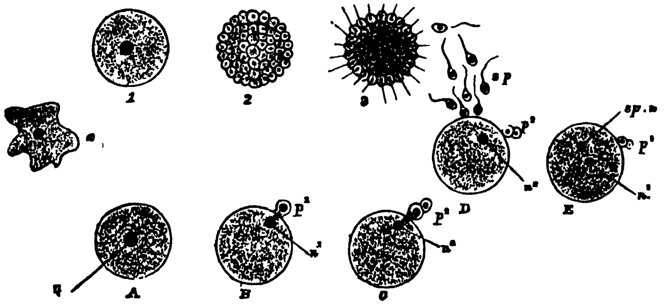


FIG. 210.—Fertilization. The diagram shows the development of spermatozoa in the upper line, the maturation and fertilization of the ovum in lower line. *a*, an amœboid sex-cell; A, ovum with germinal vesicle (*n*); B, ovum pushing out first polar body, p^1, and leaving nucleus, n^1, reduced by half; C, extension of second polar body, p^2, nucleus, n^2, now reduced to one-fourth of original; 1, a mother sperm-cell; 2, dividing into immature sperms; 3, dividing into mature sperms, *sp*; D, the entrance of a sperm into the ovum—note only one enters, as a rule; E, the male nucleus, *sp. n*, approaches the female nucleus, n^2. When these two nuclei unite, fertilization has taken place. (After *Geddes* and *Thomson*.)

dyes and so to stand out under the microscope in marked contrast to the rest of the cell (Fig. 203, F and H). The number of chromosomes in each cell is *always even* and *always constant* for each member of a species, with certain exceptions to be alluded to presently, but the number varies in different species, a few examples of which follow:

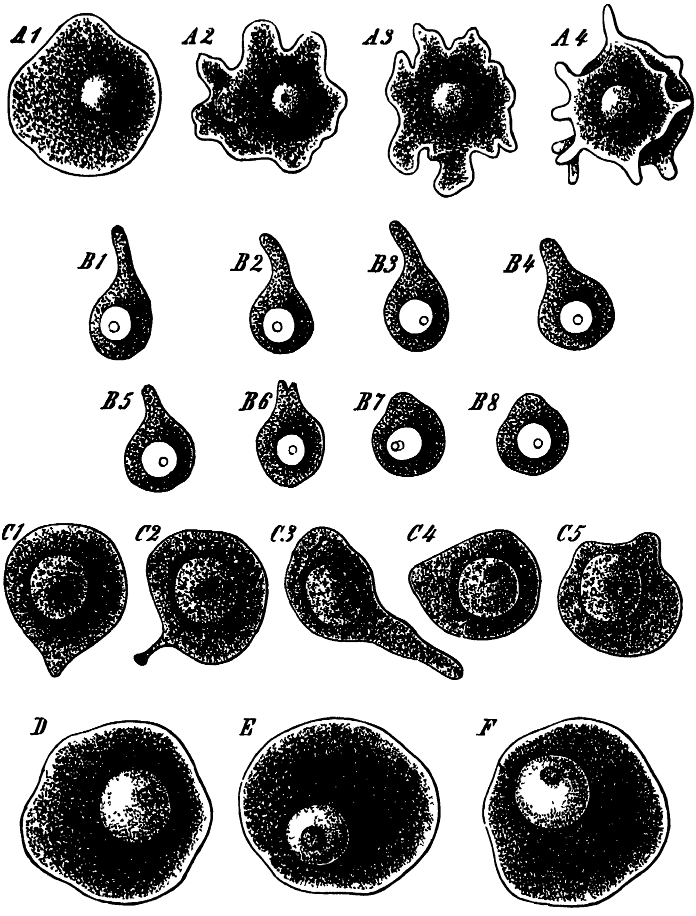


FIG. 211.—Egg-cells. A^1–A^4, of the chalk-sponge; B^1–B^8, of a hermit crab; C^1–C^5, of a cat; D, of a trout; E, of a hen; F, of man.

Organism.	*Number of Chromosomes.*
Ascaris univalens (worm)	2
Ascaris bivalens (worm)	4
Several nematode worms	8
Locust. Cricket. Spirogyra (alga). Pond-weed Naias	12
The bug	14
Onion. Wheat. Pine. Snail. Ox. Rat. Guinea-pig	16
Sagitta (worm). Sea-hedgehog (echinoderm). Ascidia (Tunicate)	18
Ant	20
Allolobophora (worm)	22
Lily. Pæony. Osmunda. Dragon-fly. Trout. Salamander. Frog. Mouse. Man.	24
Jelly-fish. Pieris (butterfly)	28
Cockroach. Sandworm. Earthworm	32
Shark. Torpedo-fish. Ass	36
Crepidula (gasteropod)	60
Crayfish	168

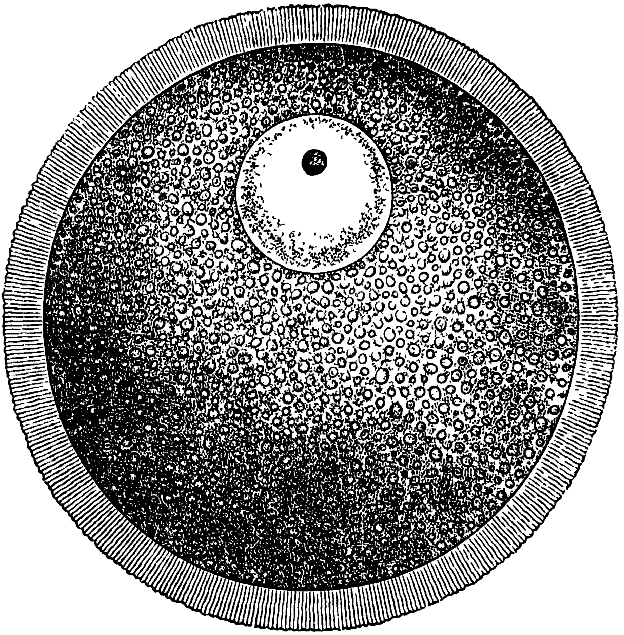


Fig. 212.—Human Ovum, mature and greatly magnified.

When the fertilized ovum or *zygote* (Fig. 213) divides to form the two daughter-cells and their successive cell-generations, all the contents of the cell—cytoplasm,

GAMETOGENESIS OF MOUSE OR MAN.

(1) The Fertilized Ovum or Zygote, *z* (*Ch* = 24).

(2) The Somatic or Body-cells, *s c.* (*Ch* = 24), and the Gametes or Germ-cells, *g.c.* (*Ch* = 24), which in the female at this stage are called *Oogonia*, *oo* , and in the male *Spermatogonia*, *sp*.

(3) Multiplication and formation of successive generations of Oogonia, oo^1, $oo.^2$, etc., in the female, and of Spermatogonia $sp.^1$, sp^2, etc., in the male.

(4) Reducing of Chromosomes (*Meiosis*) commences (*Ch* = 2 × 12) with the formation of Primary Oocytes, *p o.*, and Primary Spermatocytes, *p s*.

(5) Completion of *Meiosis* (*Ch* = 12) with formation of Secondary Oocyte *s.o.* and First Polar Body, $p.b.^1$, in the female, and Secondary Spermatocytes, *s.s.*, in the male.

(6) Formation of Mature Ovum, *m.o* (*Ch* = 12), and Second Polar Body, $p\ b.^2$, with two daughter-cells, *d c.*, of first Polar Body in the female. Formation of Immature Spermatozoa or Spermatids, *i.s.* (*Ch* = 12), in the male.

(7) Formation of Mature Spermatozoa, *m.s.*

(8) Mature Spermatozoon (*Ch* = 12) enters Mature Ovum (*Ch* = 12).

(9) Male pronucleus (*Ch* = 12) approaches female pronucleus (*Ch* = 12).

(10) Fusion of male and female pronuclei to form nucleus (*Ch* = 24) of the Fertilized Ovum or Zygote, *z*.

(8–10) Three stages, *c.g.* ¹, ², and ³, in the Conjugation of the Gametes.

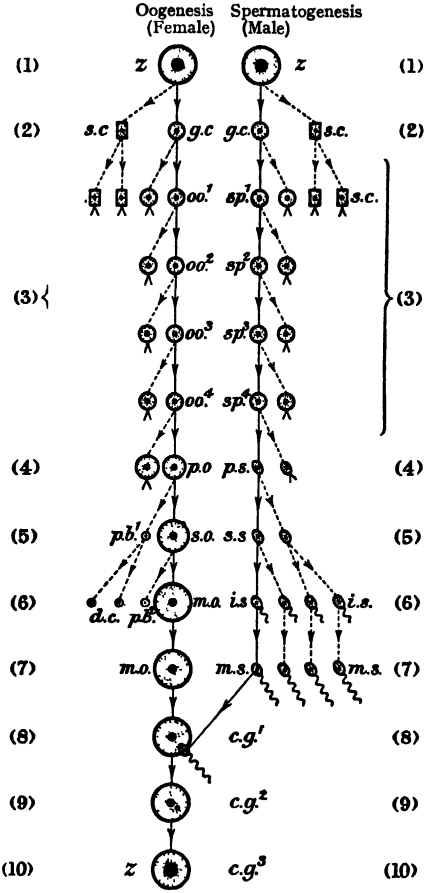


FIG. 213.—Diagram showing number of Chromosomes (*Ch*) in the various stages of Gametogenesis.

nucleoplasm, and chromatoplasm—divide as well. In this way the daughter-cells keep up the normal number of chromosomes per cell, for it is obvious that, if a cell containing, say, 16 chromosomes, as in the case of the onion or cow, divides into two and, prior to its division, each chromosome also divided into two, and if, further, one half of the split chromosomes goes to each of the two daughter-cells, then each must possess the same *number* of chromosomes as the parent-cell; in fact, each only "gets"—as Geddes and Thomson put it in their crowning work, *Life*—"a meticulously precise half of everything that is in the parent-cell." To make this important process clearer let us follow up the behaviour of these little carriers of heredity, from the fertilized egg-cell of one generation to the fertilized egg-cell of the next. We will select the mouse, since that animal is like man in possessing 24 chromosomes per cell. The fertilized or zygote egg-cell (*z*, Fig. 213) first divides into an immense number of somatic cells (*s.c.*) making up the *body* and a large, though relatively less numerous, number of germ-cells (*g.c.*) constituting the *reproductive glands* within the body. Every somatic cell and every germ-cell or gamete of the reproductive glands contains 24 chromosomes. As we have no further concern with the somatic cells we will leave them and concentrate on the gametes. These are, at their start, represented in the male as the mother sperm-cells or *Spermatogonia* (*sp.*^{1}) and in the female as the mother egg-cells or *Oogonia* (*oo.*^{1}). The reproductive glands grow to the full size by means of a succession of cell-divisions, *oo.*^{1} . . . *oo.*^{4}, etc., and *sp.*^{1} . . . *sp.*^{4}, etc., during which each cell strictly retains the normal number of 24 chromosomes. A time now comes when the latter, instead of lying in each cell-nucleus as 24 separate units, arrange themselves as 12 pairs. Such gametes containing 12 pairs of chromosomes are known in the female as *primary Oocytes* (*p.o.*), and in the male as *primary Spermatocytes* (*p.s.*), and such arrangement constitutes the commencement of a momentous event known as *Meiosis* (lessening) or the *reducing process.* Without such process it is clear that there would be a doubling of the number of chromosomes when, at each new generation, the male and female gametes fused into one cell, and this, continued, would in a very few generations lead to a state of affairs when the physical capacity of the cell to hold further chromosomes would break down. During meiosis, then, the members of each pair of chromosomes separate and pass to opposite poles of the cell; the latter splits at its equator and so becomes two daughter-cells, in each of which there are now 12 chromosomes instead of the normal 24. Such cells are called in the male *Secondary Spermatocytes* (*s.s.*) and in the female the *Secondary Oocyte* (*s.o.*) and *Primary Polar Body* (*p.b.*^{1}). At the next cell-division each chromosome splits into two, as in the initial non-reducing phases, 12 going to one, and 12 to the other daughter-cell, so that the reduced number is maintained, the cells being termed, in the male the *Spermatids* or immature spermatozoa (*i.s.*), and in the female the *Mature Ovum* (*m.o.*), the *Secondary Polar Body* (*p.b.*^{2}) and two daughter-cells of the first polar body (*d.c.*). Polar bodies are simply incomplete (aborted) ova, and their presence is due to the fact that the ovum or female gamete being so very much larger than the male gamete there is not enough protoplasm to manufacture two complete cells, so one of the pair aborts. We must leave these little " misfits " in life's stern race to their fate, which is rapid extinction, and follow up the career of the successful gametes. The Spermatids (*i.s.*) now develop motile propelling organs in the shape of long lashing tails and attain their final stage as *mature spermatozoa* (*m.s.*). All the thousands of ova and many millions of spermatozoa produced by the female and male respectively are doomed to die except the few lucky enough to meet and unite. This act is known as the *Conjugation of the Gametes* (*c.g.*) or the *Fertilization of the Ovum*. One spermatozoon (with its 12 chromosomes) breaks through the pellicle of the ovum, drops its tail, and becomes the male pro-nucleus. Chemotactism compels this male unit with " his " 12 chromosomes to rush towards the female pro-nucleus containing " her " 12 chromosomes and to fuse with " her " to form a single large nucleus with 24 chromosomes. The resulting cell, containing the original number of 24 chromosomes, is known as the zygote (*z*) or fertilized ovum, thus completing the cycle and bringing us back to our starting-point.

Such is the marvellous story of those microscopic units inside the germ-cells that convey the peculiarities and idiosyncrasies of parent to offspring and which contribute to the general make-up of fungus and lily, of tiger and turtle-dove, of the beauty and the beast.

Once fertilized, the egg-cell or zygote begins to divide into 2, 4, 8, 16, etc. cells until, in the case of a human being, after some 70 odd generations of cells have been passed through, there is brought into being a co-ordinated cell-colony composed of some thirty thousand billion little living units.

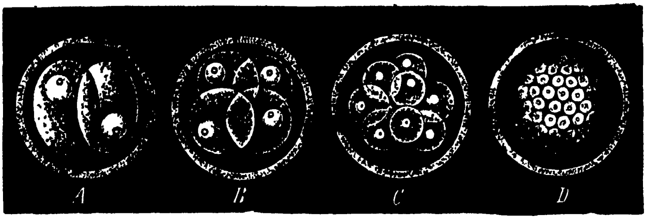


FIG. 214.—Cleavage or Segmentation of the Fertilized Egg-Cell.

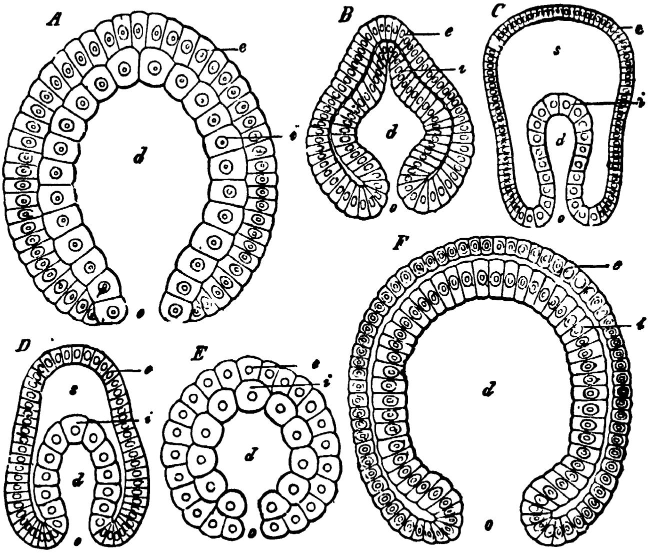


FIG. 215.—Gastrulation. *A*, gastrula of a zoophyte (Gastrophysema); *B*, of a worm (Sagitta); *C*, of an echinoderm (Uraster); *D*, of an arthropod (Nauplius): *E*, of a mollusk (Linnæus); *F*, of a vertebrate (Amphioxus); *d*, the intestinal cavity; *o*, primitive mouth; *s*, the cleavage cavity; *i*, the endoderm or intestinal layer; *e*, the ectoderm or skin layer.

After the sixteen-cell stage the embryo is a solid mass of cells called the morula, because of its likeness to a mulberry; at this stage it may be compared to those colonies of cells among the lowest animal organisms known as the moræad (Fig. 214). The cells of the morula multiply rapidly, and give rise to a *hollow* sphere, with a single layer of cells. This is the blastosphere, the cavity of which is called the *segmentation-cavity.* In the next stage the larger cells move inwards to form an inner layer, and thus arises a two-layered cœlenterate type called the gastrula (Fig. 215).

If you took a soft, hollow guttapercha ball and pushed in one half upon the other, there would be half a ball, with *two layers*, instead of a whole ball with one. This is what happens during gastrulation when the one row of cells is invaginated to form two rows. Up to this stage we have been studying the *common* life-history of animals, from a lowly plant-animal to a vertebrate (Fig. 215 A–F). In all animals above the jelly-fish there is formed, after *gastrulation,* a third layer called the *mesoblast* between the two former layers. From these three layers arise all the structures of the body:—the skin, nervous system and essential parts of the sense organs from the first or outer layer known as the *epiblast,* the lining of the alimentary canal and digestive organs from the second or internal layer known as the *hypoblast,* and the skeleton, muscles, blood-vessels and germ-cells from the last-formed or middle layer called the *mesoblast.*

Everyone is familiar with the general appearance of a fish's gills, but few people realize that they figure not only in our pedigree, but in our individual development, and that every cat, dog, and man possesses their relics. Their arrangement in the fish is shown in Figs. 216 and 217. In the latter figure we see how the symmetrically disposed blood-vessels in the fish become modified in the bird and the mammal in such manner that the main blood-stream turns to the bird's *right,* but to the mammal's *left* side.

We see further that both in the bird and the mammal these arches begin on the original plan required for a fish, but the heart has become a far more complex organ, and most of the gill-arches have disappeared. Note that though mammals and birds have come through fish-ancestors with the same number and arrangement of gill-arch blood-vessels, yet the main artery in mammals is not on the same side as that in birds.

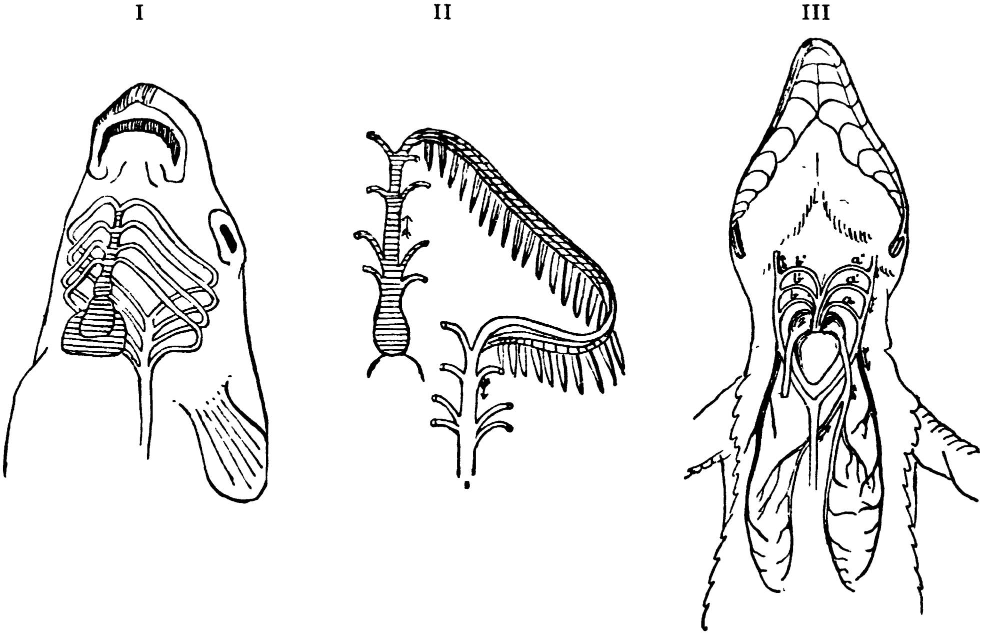


FIG. 216.—Hearts and Gill-arches. I, diagram of heart and gill-arches of a fish; II, one gill-arch with branchial fringe attached; III, heart and gill-arches in a lizard. The gill-arches, *a*, *a'*, *a''*, and *b*, *b'*, *b''*, are called aortic arches in air-breathing vertebrates.

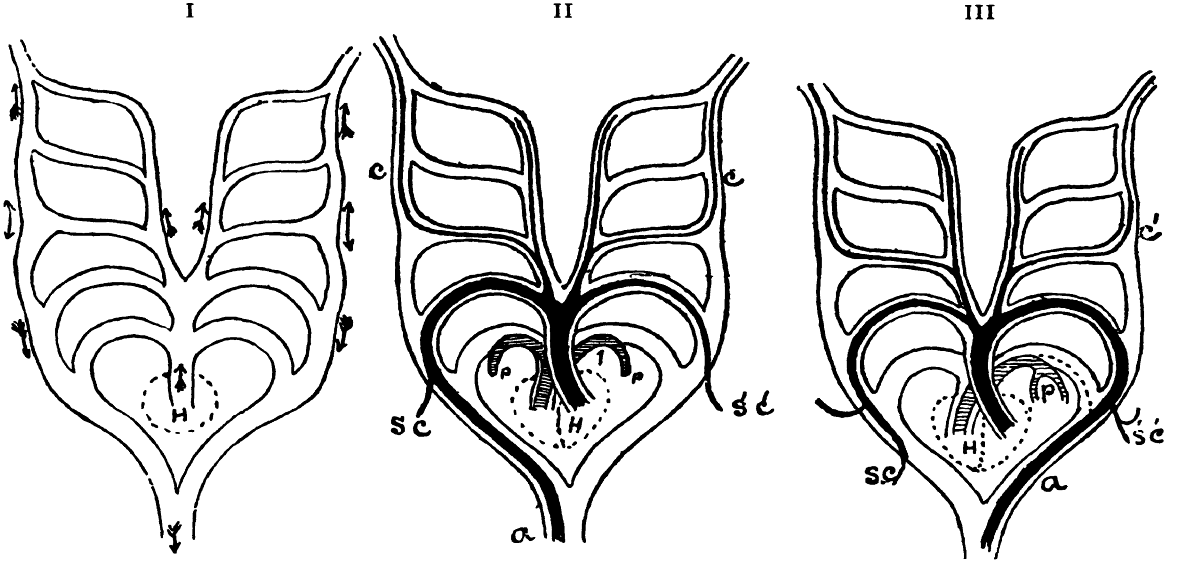


FIG. 217.—Schematic arrangement of Aortic arches or Gill-arch blood-vessels in Fish (I), Bird (II), and Mammal (III), as seen from the front. H, heart; *p*, pulmonary artery; *c c'*, carotid arteries; *s c*, *s'c'*, subclavian arteries; *a*, aorta, the main artery to the trunk and lower limbs. In man the first or mandibular and second or hyoid arches atrophy. The third becomes the first part of the internal carotid artery; the fourth, on the right side, forms the subclavian artery, on the left a part of the aorta. The fifth and sixth supply the lungs, the sixth, in addition, persisting as part of the right pulmonary artery and *Ductus Arteriosus*.

This, again, presents a question which only evolution can answer: If mammals and birds have not come from a common ancestor, why do they begin exactly alike in this respect, only to *waste* more than half these gill-arches and adopt quite a different permanent arrangement?

RUDIMENTS

Figs. 218 and 219 depict various animals in three pre-natal stages. In every instance in the top line can be seen the gill-clefts, and they are as evident in the chick and in man as in the fish. These gill-clefts carry us back several million years, before man's ancestors dwelt on the land. In all animals these and many other now useless structures appear, survive for a brief time and then either completely disappear or become modified into useful parts. In certain cases, however, a useless structure may persist, as such, throughout life. Before birth the horse passes through a stage that was permanent in the adult Miocene Hipparion, for the embryonic foal has three toes to its feet though born normally as a one-toed animal. Sometimes, however, the two additional and now useless Miocene toes fail to disappear before birth, and then we have that curious " monstrosity," a three-toed horse. How are such utterly useless structures to be explained? " What mean the unused gill-clefts of reptiles, birds and mammals," asks Sir Arthur Thomson, " unless the ancestors of these classes were fish-like? What mean the teeth of very young whale-bone whales, of an embryonic parrot and turtle, unless they are vestiges of those which their ancestors possessed? There are similar vestigial structures among most animals. In man alone there are about seventy little things which might be termed rudimentary; his body is a museum of relics. We are familiar with unsounded or rudimentary letters in many words; we do not sound the ' o ' in leopard or the ' l ' in alms; but from these rudimentary letters we read the history of the words."

Not only structures but actions may be vestigial, such as the preliminary turning round and round of a dog about to lie on the hearthrug, and the raising of the upper lip when a young lady sneers. The ancestral dog had to make a " form " in the long grass wherein to sleep,

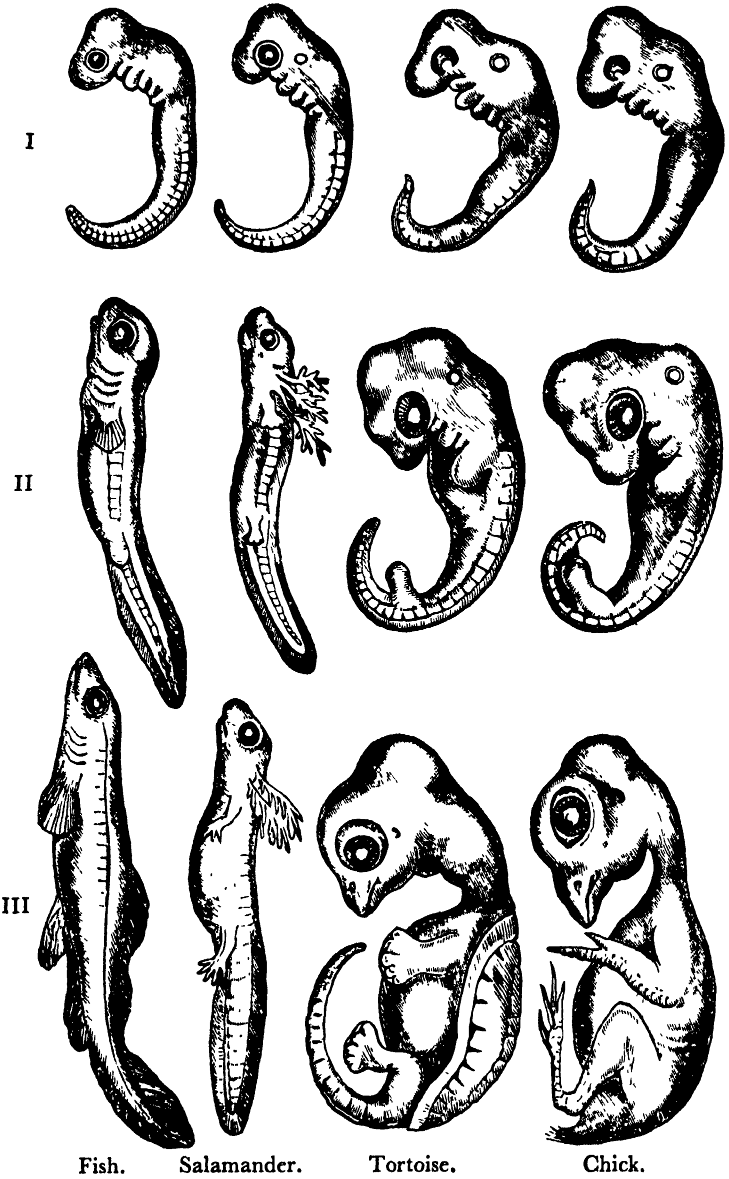


Fig. 218.—A Group of Embryos.

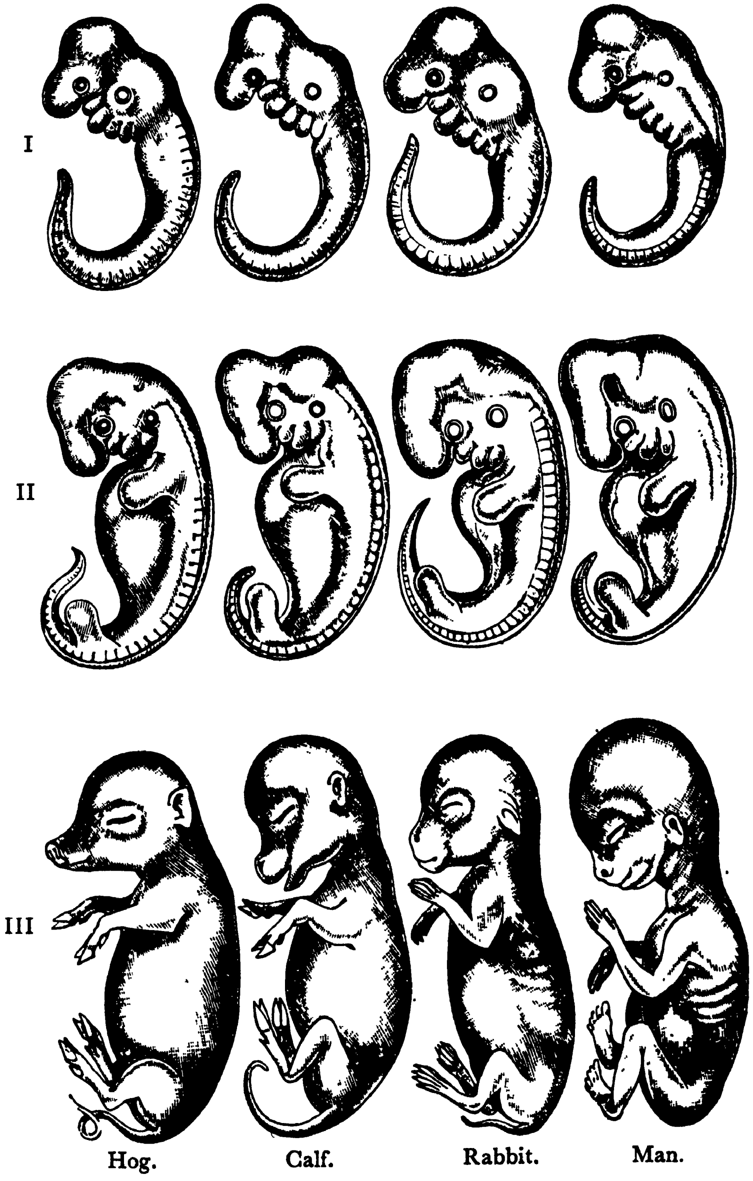


FIG. 219.—A Group of Embryos.

the ancestral lady had to show canine teeth if danger threatened her or her young! We of to-day are much further away in time from our swimming, than from our climbing, ancestors, and so it has come about that, while retaining the climbing instinct, we have lost that for swimming, so much so, indeed, that, though a baby can often hold a spoon in its toes, it is utterly helpless in the water, and even an adult man who has not *learnt* to swim *clutches* at the water as though it were a branch when he falls overboard into the sea. Even strong swimmers, when reason is swamped by instinct in the last moments of exhaustion, throw up their arms and grasp frantically at imaginary branches, hence the saying: " Drowning men clutch at a straw."

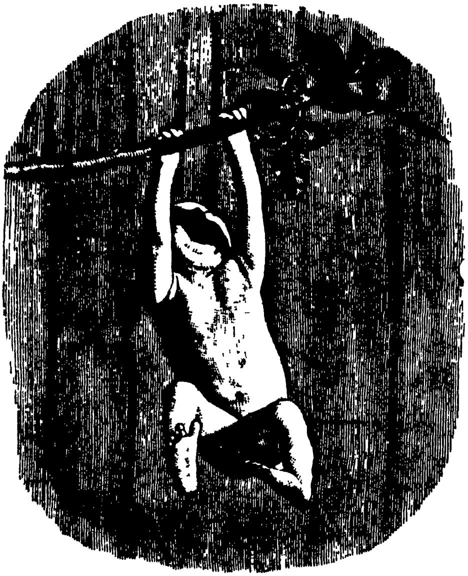


FIG. 220.—An Infant three weeks old, supporting its own weight for over two minutes. The attitude of the lower limbs, feet, and toes is strikingly ape-like. (From an instantaneous photograph by *Dr. L. Robinson.*)

Infants bend their feet inwards, so that the soles, in a great measure, face one another. This is still more marked in the embryo. (See " Man," bottom line, Fig. 219.) It plainly refers to a state of things among the

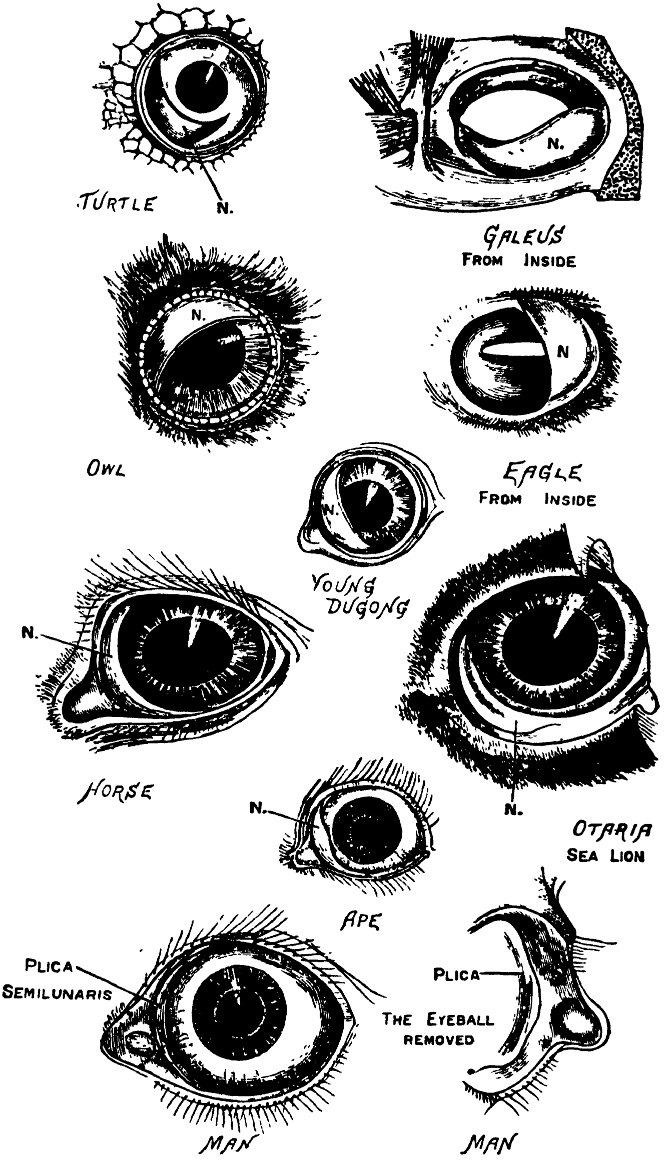


FIG. 221.—Illustrations of the Nictitating Membrane in the various animals named. The letter N indicates the membrane in each case. In man it is atrophied and known as the *plica semilunaris*. In the case of *Galeus*, a shark, the muscular mechanism is shown.

simians, in all of whom the feet are turned inwards to help them to grasp the branches.

The clenching power of the hand *and foot* is very remarkable in the human infant for the first few weeks after birth. The young of apes give us the reason for this, since by clinging with both hands to the hair of their mother's armpits, and encircling her body with their legs, they leave all her limbs free for climbing. Dr. Louis Robinson was the first to demonstrate the extraordinary power of the human infant in clinging to a branch and so supporting its own weight for som minutes (Fig. 220). Recent experiments in America hav shown that the negro baby only a few days old can han on by its hands from a stick for a much longer time tha the white.

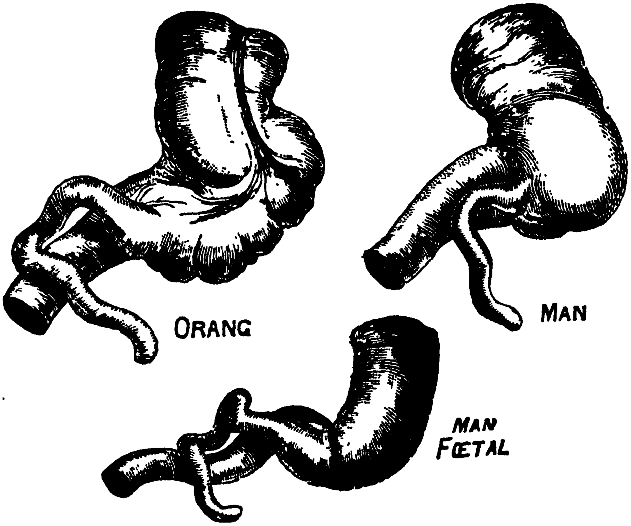


FIG. 222.—The Appendix Vermiformis (the worm-like appendix).

Throughout the vertebrate series there occurs in th inner corner of the eye the remains of a transparent eyeli called the nictitating membrane (Fig. 221). Its functio in those animals where it is fully developed (one ca often see fowls using it) is to sweep over the surface the eye both to clean and to protect it. Why do th horse and man possess this shrivelled-up relic? Becau they are descended from some common set of ancesto in whom this cleansing and protective eyelid was functional as it is to-day in the birds, tailless Amphibians, some sharks, and many reptiles.

In Fig. 222 we see the organ which, when inflamed, is the source of that troublesome disease, appendicitis. The appendix is the worm-like tag attached to the big bowel just below its junction with the small one. This structure is large and useful among many herb-feeding animals, but in man it serves no such purpose, and, indeed, is a source of danger. In the orang it is bigger than in ourselves, and in the fœtus of man and ape it is relatively larger than in the adult.

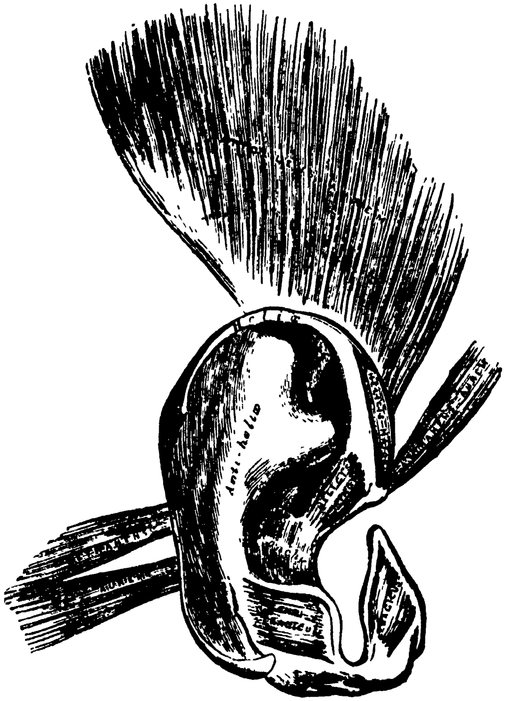


FIG. 223.—The rudimentary, or vestigial and useless, muscles of the human ear.

In Fig. 223 are shown the useless muscles of our ears, relics of those that enabled our wild ancestors to move these organs so as to catch every sound, just as horses and foxes do to-day. Human beings and the higher

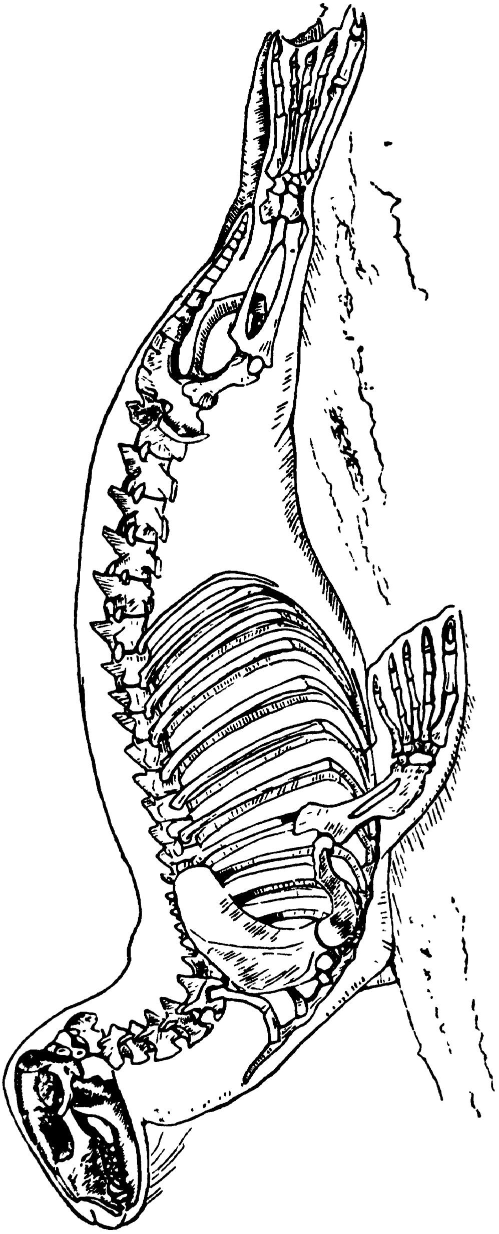


Fig. 224.—Skeleton of a Seal.

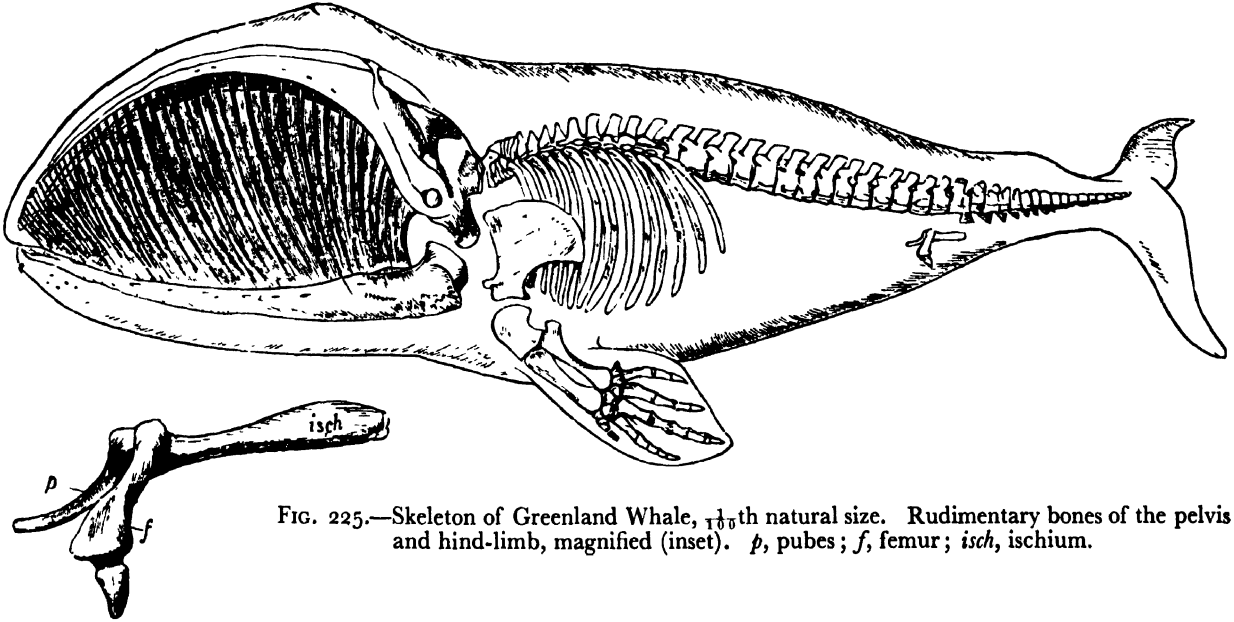


FIG. 225.—Skeleton of Greenland Whale, $\frac{1}{100}$th natural size. Rudimentary bones of the pelvis and hind-limb, magnified (inset). *p*, pubes; *f*, femur; *isch*, ischium.

apes have almost entirely lost this power to move their ears, though here and there an individual turns up who can do so to a slight extent.

The seal and the whale (Figs. 224, 225) are warm-blooded mammals that have come from four-legged terrestrial ancestors. In the seal we see all the bones of the hind legs shortened up and directed backwards, till they form a false tail which lies behind and below the relic of the true one. So comparatively recently—say twenty million years ago—has the seal taken to aquatic life that every baby-seal still has to receive lessons in swimming from its mother. In the whale only the front limbs remain externally, but inside the animal are the remains of the limb-girdle (*p*) and the thigh-bone (*f*). In 1921 a female whale was caught off British Columbia with a pair of hind legs that projected externally from the body near the tail for some four feet.

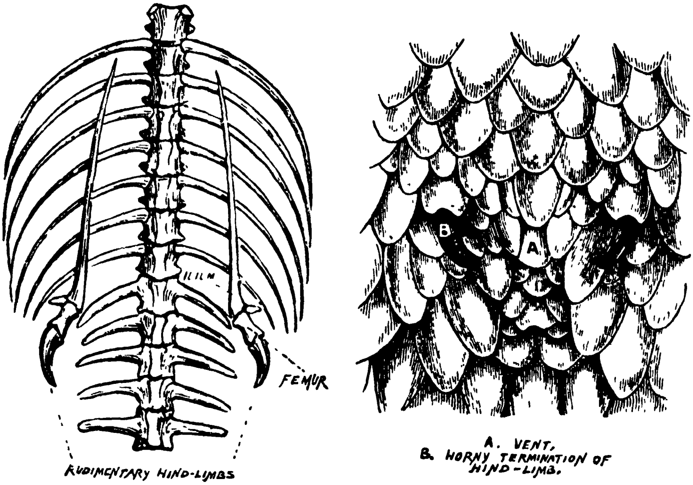


FIG. 226.—Hind limbs of the Python.

It is almost insulting intelligence to ask which explanation is the more satisfactory, that the whale's useless hind legs and its hand fingers, so encased in fin-like sacks as to be incapable of prehension, were specially created in such a form or that they are the natural outcome of evolutionary processes, in the case of the hind legs of degeneration consequent on disuse, and of the hands, of modification consequent on change of function.

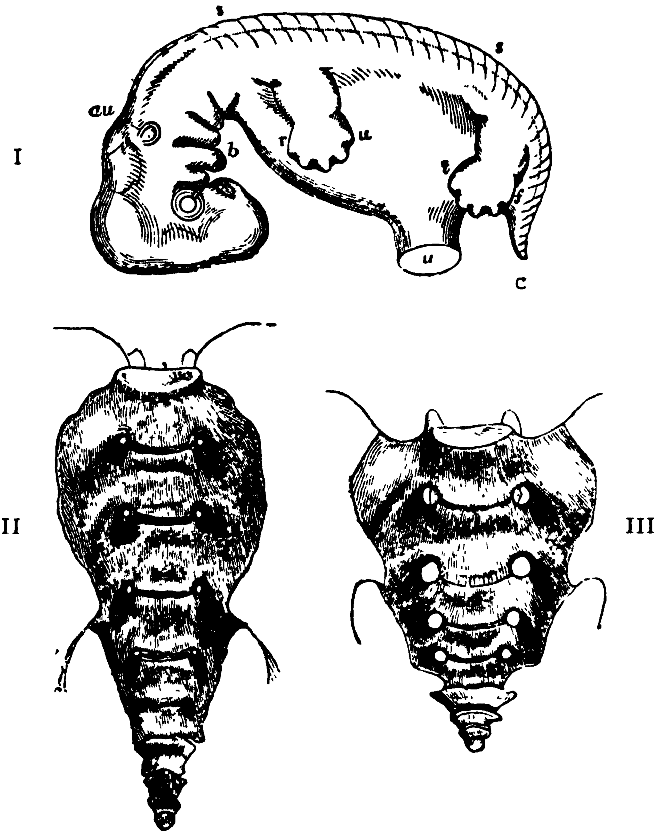


Fig. 227.—On Tails. I, outline of the human embryo, about seven weeks old, showing the relation of limbs and tail to the trunk. *r*, the radial, *u*, the ulnar border of the hand and fore-arm; *t*, the tibial, and *f*, the fibular border of the foot and the lower leg; *au*, ear; *s*, spinal column; *u*, umbilical cord; *b*, gill-slits; *c*, tail. II, sacrum of Gorilla, and III, of Man, each showing the rudimentary tail-bones.

Equally striking is the case of the python, whose useless legs are slowly rotting away, so to speak, in the depth of its belly, the little black toe-nails, peeping out from the ventral scales, being all that remain visible (Fig. 226).

Fig. 227 shows us a gill-clefted animal with webbed limbs and a tail longer than its hind legs. It is embryonic man. Not only, at this early stage, has man a tail, but he has the remains of the muscle, the *Agitator caudæ*, that once moved it about. Anthropoid apes also possess a relatively long tail before birth but, like man, no visible tail after that event.

Could anything show more clearly that man has come from a quadrupedal, tailed ancestor? Fig. 228 shows an actual photograph of the human embryo in the externally-tailed condition.

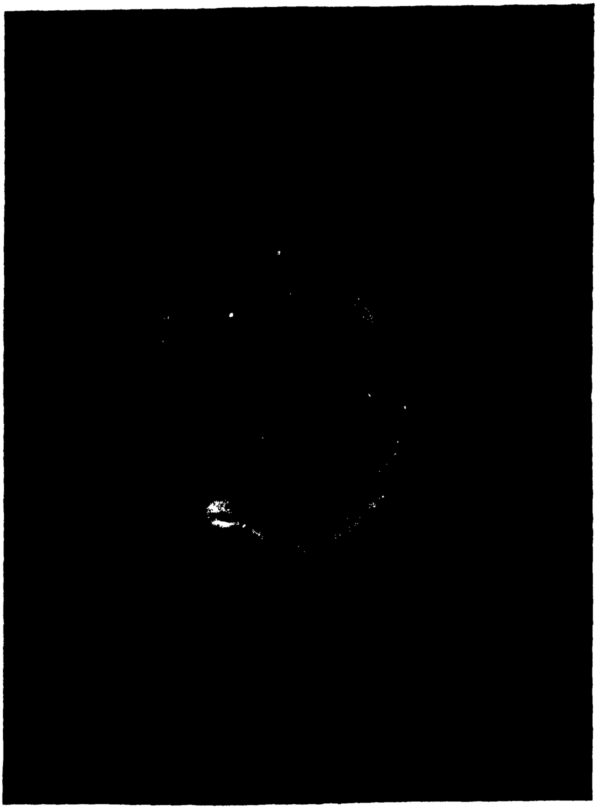


Fig. 228.—A Human Embryo from the thirty-second to the thirty-fifth day—*i.e.* about the fifth week. Enlarged about three diameters. (From *Professor Arthur Thomson.*)

CHAPTER TEN: PEDIGREE OF MAN

IN all cases, except perhaps in a few American Fundamentalist Universities, biologists now teach that man, together with lemurs, monkeys, and apes, belongs to the Primate group. Though he belongs specifically to one group, he is related closely or remotely to every living being. Consequently, working backwards we should seek man's origin first in some primitive mammal from which all mammals have arisen, then in some simple vertebrate who was the common ancestor of all backboned creatures, next in a primitive metazoon that gave rise to all multicellular animals, then in a primitive protozoon from which the whole animal kingdom sprang, and, finally, in some primordial form of protoplasm, some very primitive and possibly ultra-microscopic protist that formed the common starting-point of all plants and animals. Biologists are now agreed that just as at one stage in our cooling planet there occurred the evolution, by synthesis, of the chemical elements from pre-existing simple atoms and simpler subatoms, so at another and later stage there took place the further synthesis of living matter—a form of protoplasm probably far more simple and primitive than that with which we are familiar—from pre-existing inorganic colloidal solutions. This theory of the origin of life is known as *Abiogenesis.*

In lowly one-celled organisms a larger individual sometimes " swallows up " a smaller one of the same species, after which process it becomes more active and divides rapidly for a considerable period (Fig. 229). The absorbed cell has not only acted as *nutrition* but also as a *chemical stimulus* to the larger one. Further, as it is probable that all the protoplasm of the smaller cell is not used up as food, but remains alive, " mixed up " with the protoplasm of the larger cell, there results, from the joined forces, not only a reinvigoration of the newly-formed cell as a whole, but a reaping, so to speak, of new experiences. The single cell thus resulting from the fusion of *two* now carries within itself the combined hereditary experiences of two individuals, and hence it becomes more resourceful in reacting to its environment. Such, undoubtedly, is the origin and function of sex-union.

The Amœba (Fig. 230) recognizes the difference between a particle of food and a particle of sand b chemical attractions and repulsions, a property in a protoplasm known as " irritability." Such " attractions are somewhat ponderously termed "*positive chemotaxis,* while the repulsions are known as " *negative chemotaxis.* The *cell-fission,* that forms one aspect of reproduction, is at bottom, discontinuous growth; the *cell-fusion,* tha constitutes the other aspect, is essentially a chemotacti process. The unfertilized ovum is positively chemotactic, the fertilized ovum negatively chemotactic, to a. male gametes. The basis of the emotions of love and hate is biochemical!

Another great stage in growth occurred when th cells, after dividing, did not separate, but clung togethe in a somewhat loose fashion to form colonies. This wa the grand step to the formation of a " body "; it wa the dawn of co-operation. All the intelligence and beauty and triumph of the human race owe their origin to thi step.

Yet another important step in the upward climb o evolution was the acquisition of a hollow body—it gave us our food-canal.

The acquirement of special apparatus in the shape o a nervous system that enabled the organism to be in constant and quick communication with the outer world added almost infinite power to the animal race. At first the skin had to play the rôle of nervous system, because it was the only connection between the animal and its environment. From this simple beginning there developed, through division of labour in the cell-colony the elaborate nervous system of the higher animals, giving them their greater intelligence.

After many millions of years the " back " of certain worm-like creatures (Fig. 240) became stiffened by the presence of a gristly rod, the notochord, which was to prove the scaffolding, as it were, for the true backbone of the fish. In this way vertebrates came on the scene.

Very gradually the aquatic vertebrate became the terrestrial vertebrate through fins becoming legs, air-bladder being turned into lungs, and gills into various other structures more adapted to life ashore. We can to-day glimpse how such transitional stages from water to land occurred by observing sea and land crabs, the double-breathing fishes, the tadpole and frog, and the water-land life of many insects such as mayflies and dragonflies.

At long last the terrestrial quadruped took to climbing trees and this arboreal life led to specialization of fore-feet into grasping hands. But the specialization of fore limbs in the one direction led to specialization of hind limbs in another, viz. entire support of the body. Thus was brought about the erect gait with its enormous advantage of being able to see well around one without climbing trees. So our man-in-the-making forsook arboreal life, came out into the open and, thanks to his freed hands, became a tool-making animal and, finally, the builder of houses, cities, railways, ships, aeroplanes, and wireless.

We must remember that: (1) no one pretends to know the exact ancestor of this or that race of men; (2) man evolved through various groups of animals; (3) in no case are *living* groups the *unaltered* ancestors of man.

The Amphioxus or Lancelet (Figs. 240 and 242) is of the utmost interest as showing how Vertebrates may have arisen from Invertebrates. The remote vertebrate ancestor was probably a sand-burrowing and free-swimming sea-worm of the Balanoglossus (Fig 239) type. Burrowing necessitated a certain amount of rigidity, and so the stiffening notochord was evolved. Swimming necessitated rapid movement through water and maintenance of correct orientation, so primitive fin-folds came on the scene. We can see such beginnings to-day in larval Ascidians and Appendicularia (Figs. 240 and 241). It was not long, geologically speaking, before descendants exploited these structures, the gristly rod developed first into the cartilaginous backbone of primitive fishes (Fig. 245), and finally into the bony vertebræ of the true fishes and land-vertebrates, while the primitive fin-fold became divided first into fins and later into limbs.

All existing Primates, from lemur to man, are to be regarded as the terminals—the leaves—of branches that have successively diverged from the mammalian stem since Eocene times. Most remarkable evidence of the relationship binding together all members of the animal kingdom is given by certain blood reactions. It has long been known that if the blood cells of one animal be injected into the blood-stream of another they are sooner or later destroyed by certain chemicals called *cytolysins* (cell-dissolvers). The rapidity of this destruction varies according to the closeness or remoteness of blood-relationship, being slow where the species of the two animals concerned is identical, rapid where they are widely different. The blood cells of a human being injected, say, into the blood of a dog are killed very quickly; if into the blood of a lower monkey they are killed less quickly; if into the blood of an anthropoid ape, the destruction of the cells takes place so slowly that the net result is practically the same as when the blood of two human beings is mixed together. This curious behaviour is owing to the fact that the blood of any one species differs markedly in chemical composition from that of all other species, while the blood of a member of any one species is almost, *but not quite*, identical in chemical composition with the blood of another member of that species. *The degree of difference of the blood of animals is directly connected with the degree of relationship between them.* Professor Nuttall of Cambridge has devised an exquisitely sensitive test whereby this degree of difference between two bloods, and consequently the proximity or remoteness of the two animals concerned, can be measured with great accuracy. Clear colourless serum from human blood is injected at intervals into a vein of a rabbit. After some days this rabbit's blood will be found to have acquired remarkable properties. If a drop or two of its clear serum be added to human serum a heavy white precipitate is formed almost immediately. Practically the same result ensues if, instead of human, anthropoid ape serum is used. If added to the serum of a lower monkey or lemur, a precipitate is also formed, but more slowly and less abundantly. The amount and rapidity of formation of the precipitate decreases steadily as we descend the Primate and mammal scale. Such blood-test, apart from its more practical utility in criminology and law—for it has already been made legal use of to throw light on human relationships—has proved that:

1. Man is definitely related to all mammals and very closely to the higher Primates.

2. The Carnivora are more closely related to one another than to the Herbivora.
3. Whales are closely related to, and have therefore almost certainly descended from, mammals of the pig type.
4. Limulus, the King Crab, is not, as many zoologists had claimed, a true crab, but is more akin to members of the spider and scorpion groups.
5. Birds are very closely connected with the reptiles. The aphorism, " Birds are but glorified reptiles," is thus confirmed.

We will now pass in review a number of groups showing the probable pedigree of man from the dawn of life.

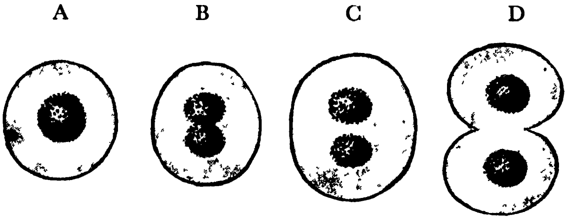


FIG. 229, Group I.—*Chroococcus Minor*, magnified 1,500 times. The unnucleated bluish-green globule of plasm increases by simple cleavage. The central zone of each cell stains more deeply than the remainder, giving the appearance of a nucleus, but this is not the case.

GROUP I

Group I contains only Monera, from the lowest level of the plant world. They are among the simplest organisms known to us, being mere particles of plasm or protoplasm with little organic structure (Fig. 229).

GROUP II.—AMŒBÆ

The Amœba stage marks a distinct advance in cell-structure, the nucleus and cell-body being now well-defined. Remember that the young unfertilized human ovum looks and behaves like an Amœba (Figs. 230 and 231).

GROUP III.—MORÆADS

Here we attain a stage where separate cells have clustered together to form a multicellular colony shaped somewhat like a solid ball, such as may be seen in various Moræad types (Fig. 232).

GROUP IV.—BLASTÆADS

In this stage the solid ball of cells, or Morula, becomes a hollow sphere, the Blastæad or Blastula, the wall of which is composed of a layer of single cells called the Blastoderm (Figs. 233 and 234; see also Fig. 159 [3, 9]).

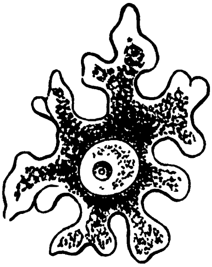


FIG. 230.

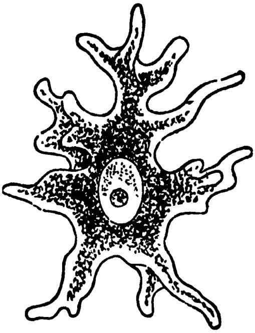


FIG. 231.

FIG. 230, Group II.—An Amœba (highly magnified). The whole organism is simply a naked cell, and moves about by means of the variable processes that it thrusts out and withdraws into its protoplasmic body. There is a clear, round nucleus in the middle of it.

FIG. 231, Group II.—The Ovum of a Calcareous Sponge (*Calcolynthus*). The ovum creeps about in the body of the sponge, by the same means as the Amœba. This helps us to see how the ovum of the higher animals may have come from an ancient ancestral form, like the common Amœba.

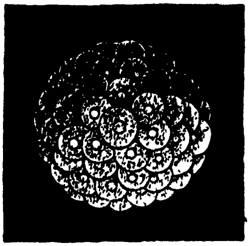


FIG. 232, Group III.—A common example of a Moræad; the morula, or mulberry-shaped embryo. It is really a colony of Protozoa, and there are many plants and animals in this form which never advance any further.

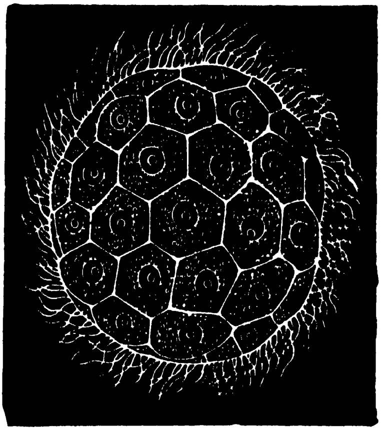


FIG. 233, Group IV.—The Norwegian *Magosphæra planula*, swimming about by means of the lashes or cilia at its surface.

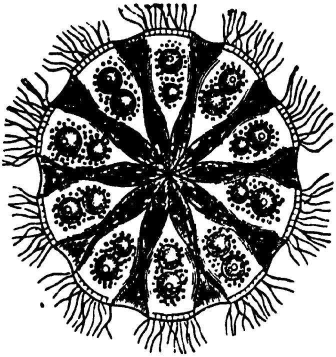


FIG. 234, Group IV.—Section of Fig. 233, showing how the pear-shaped cells in the centre of the gelatinous ball are connected by a fibrous process. Each cell has a contractile vesicle as well as a nucleus.

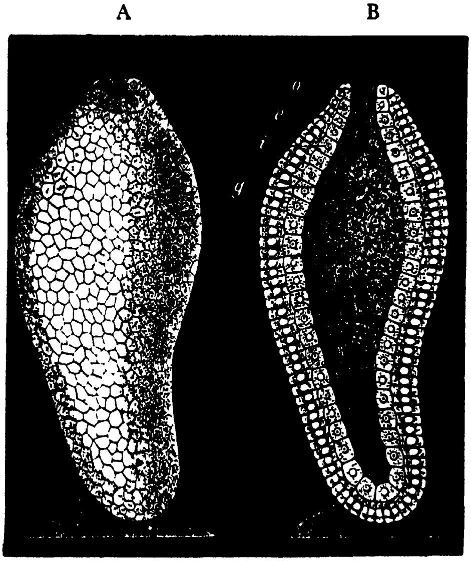


FIG. 235, Group V.—A Gastrula Form, the ascula of Gastrophysema, attached to the floor of the sea. A, the external view; B, a longitudinal section; *g*, primitive gut; *o*, primitive mouth; *i*, visceral layer; *e*, cutaneous layer. See also Figs. 84, 215, and 159 (4, 10).

GROUP V.—GASTRÆADS

Presently one part of the single cell layer constituting the Blastoderm falls in upon the other part to form a two-cell layer known as the Gastræad (Fig. 235).

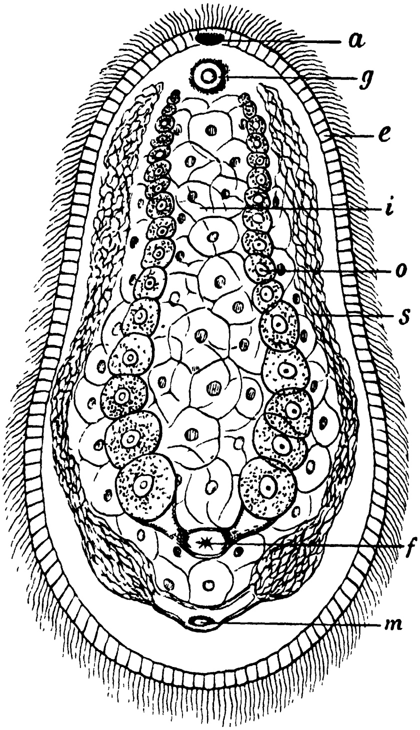


FIG. 236, Group VI.—One of the Platodaria, *Aphanostomum Langii.* *a*, Mouth; *g*, auditory vesicle; *e*, ectoderm; *i*, entoderm; *o*, ovaries; *s*, spermaries; *f*, female aperture; *m*, male aperture.

GROUP VI.—PLATODES

In this and the next group we pass through our worm-like ancestors. From the bilateral Gastræads arose in all probability the Platode worms (Fig. 236) and from these the Turbellarian worms (Fig. 237). The Parasitic worms, being hopeless degenerates, need not concern us in our study of *upward* evolution. But the Turbellaria are of especial interest from the light they throw on the evolution of the alimentary canal, for they exhibit the bowel in its first and most primitive form of a straight narrow tube, hence another name of these creatures is "straight-guts," all higher animals being "crooked guts."

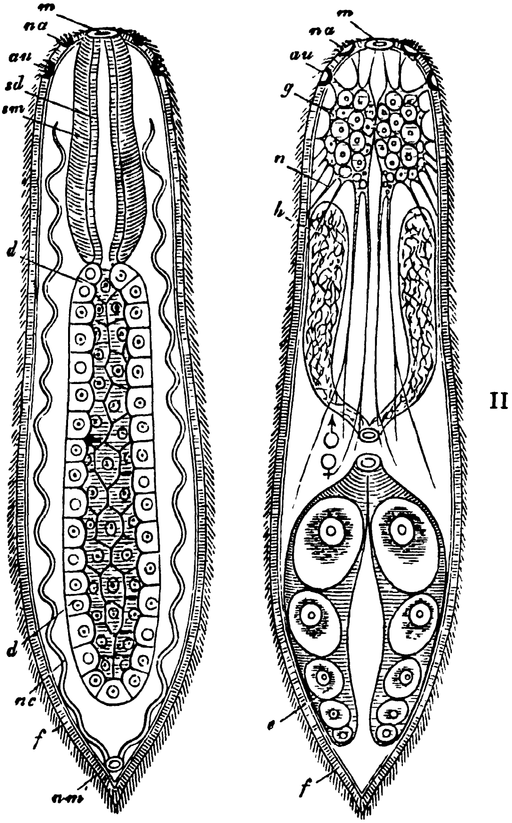


FIG. 237, Group VI.—I, One of the Turbellaria, a simple coiled-worm (*Rhabdocœlum*). *m*, Mouth; *sd*, gullet epithelium; *sm*, gullet muscles; *d*, gastric duct; *nc*, renal canals; *nm*, renal aperture; *au*, eye; *na*, olfactory pit. II, The same, showing the other organs. *g*, brain; *au*, eye; *na*, olfactory pit; *n*, nerves; *h*, testicles; ♂, male aperture; ♀, female aperture; *e*, ovary; *f*, ciliated epiderm.

GROUP VII.—VERMALIA

Coming to the worms proper or *Vermes* we pass over the *Gastrotricha* (Fig. 238) to the snout-worms or rhynchocœla (Fig. 239). Balanoglossus, the acorn-worm, is probably a survivor of the ancient gut-breathing Vermes (Enteropneusts) from which the Vertebrates ultimately took origin. There is a close connection between Balanoglossus and Appendicularia (Fig. 241) and both these

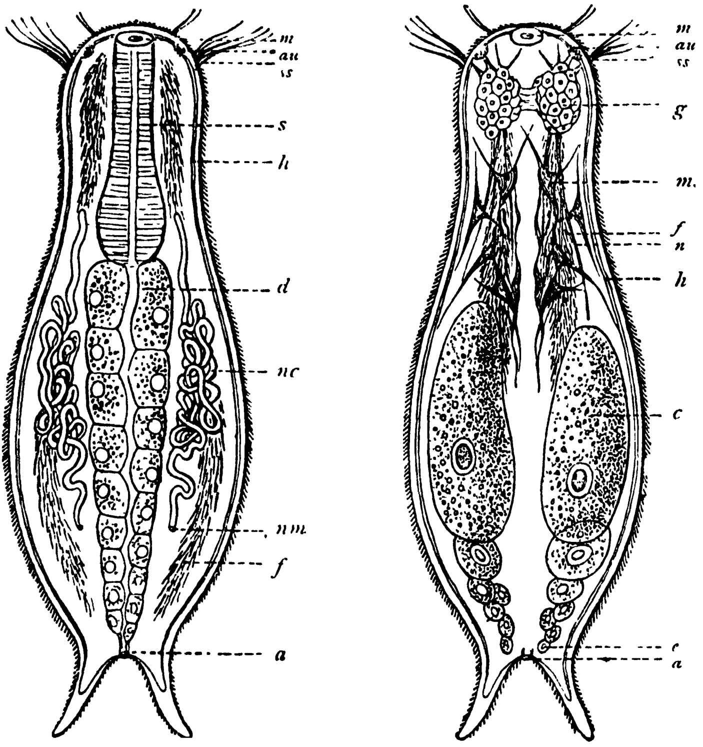


FIG. 238, Group VII.—Two views of the *Chætonotus*, a rudimentary vermalian of the group Gastrotricha. *m*, Mouth; *s*, gullet; *d*, gut; *a*, anus; *g*, brain; *n*, nerves; *ss*, sensory hairs; *au*, eye; *ms*, muscular cells; *h*, skin; *f*, ciliated bands of the ventral surface; *nc*, nephridia; *nm*, their aperture; *e*, ovaries.

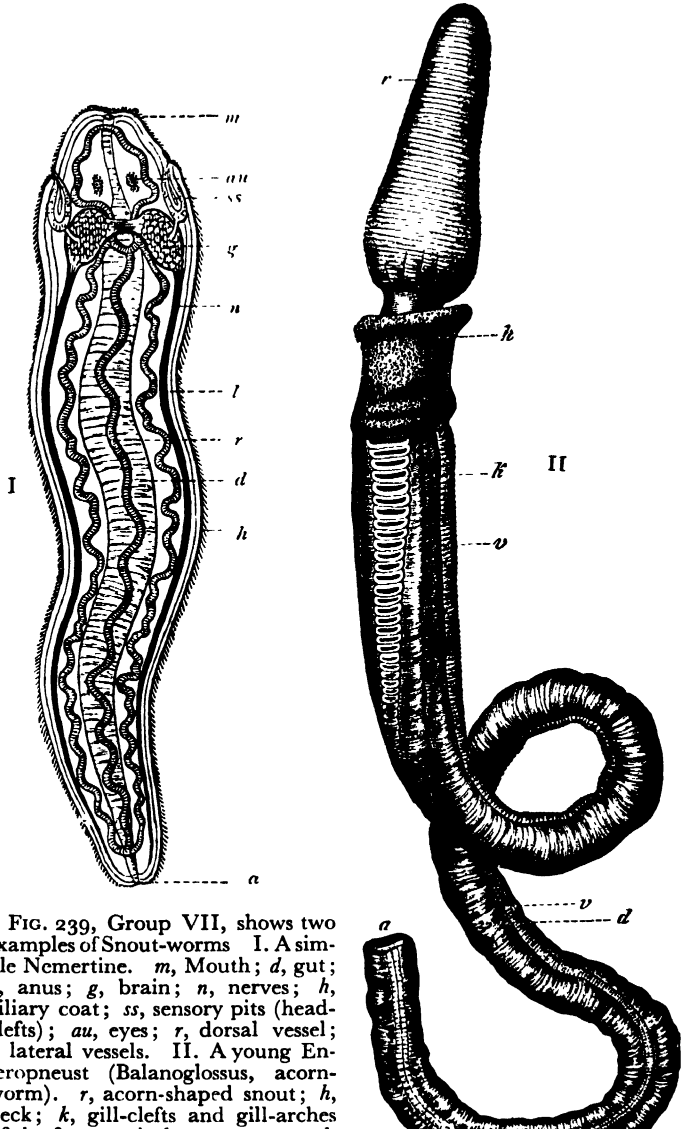


FIG. 239, Group VII, shows two examples of Snout-worms I. A simple Nemertine. *m*, Mouth; *d*, gut; *a*, anus; *g*, brain; *n*, nerves; *h*, ciliary coat; *ss*, sensory pits (head-clefts); *au*, eyes; *r*, dorsal vessel; *l*, lateral vessels. II. A young Enteropneust (Balanoglossus, acorn-worm). *r*, acorn-shaped snout; *h*, neck; *k*, gill-clefts and gill-arches of the fore-gut in long rows on each side; *d*, digestive hind-gut, filling the greater part of the body-cavity; *v*, intestinal vein or ventral vessel, lying between the parallel folds of the skin; *a*, anus.

are nearly related to Amphioxus (Figs. 240 and 242). All three organisms are of immense value in throwing

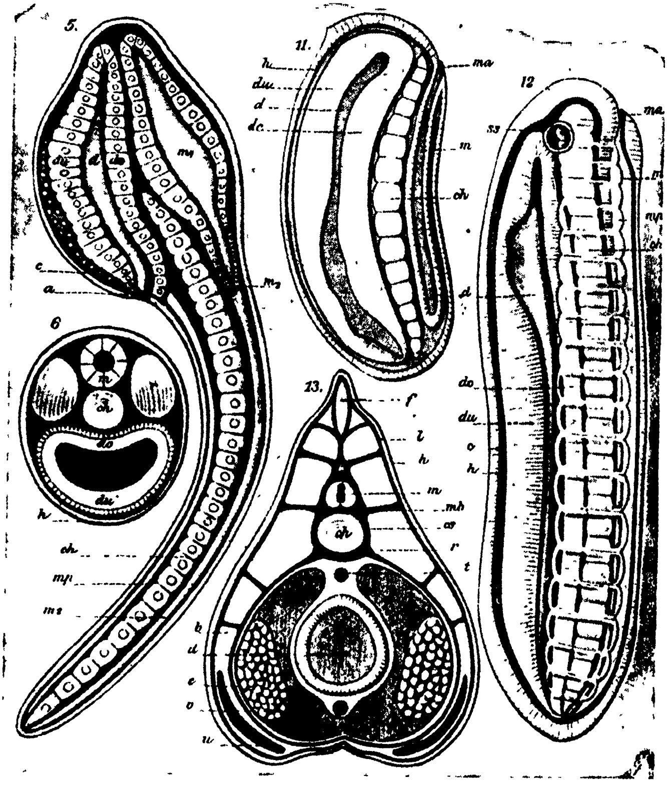


Fig. 240, Group VIII.—Larva of the Ascidian and Larva of the Amphioxus show some striking likenesses, which are of great importance, as the Amphioxus is so clear a link in the history of Vertebrates. 5, The free larva of the Ascidian. Between the medullary tube (*m*) and the alimentary canal (*d*) the chorda (*ch*) passes and goes the whole length of the tail to the tip. 6 Is a transverse section of 5. The section is just the same as that of the Amphioxus larva (11 and 12). 11, Young larva of the Amphioxus; *m*, *d*, and *ch*, as in 5. 12, An older larva of the Amphioxus, with letters meaning the same; *ma* is the opening of the medullary tube at its anterior end. See also Figs. 87, 88, 89.

light upon the evolution of the Chordates from the pro Chordonia; they are the Adams and Eves of Vertebrates

GROUP VIII.—PROCHORDONIA

To wrest the secrets of evolution from the "before-the-Chordate" animals, the Ascidians or Tunicates, we must study them in their *larval* state (Fig. 240), for the adult is so degenerate that it has lost most of the higher features of its youth. Some Ascidians, however, such as the *Copelata* (Fig. 241), retain throughout life the *notochord* and *nerve-cord* that are the equivalents respectively of the backbone and spinal cord of higher verte-

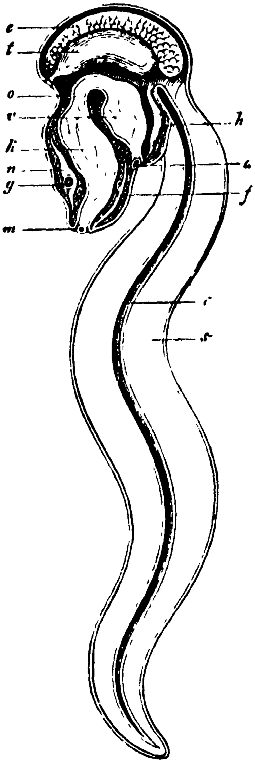


FIG. 241, Group VIII.—An Appendicularia (*Copelata*), seen from the left. *m*, Mouth; *k*, branchial gut; *o*, œsophagus; *v*, stomach; *a*, anus; *n*, brain (ganglion above the gullet); *g*, auditory vesicle; *f*, ciliated groove under the gills; *h*, heart; *t*, testicles; *e*, ovary; *c*, chorda; *s*, tail.

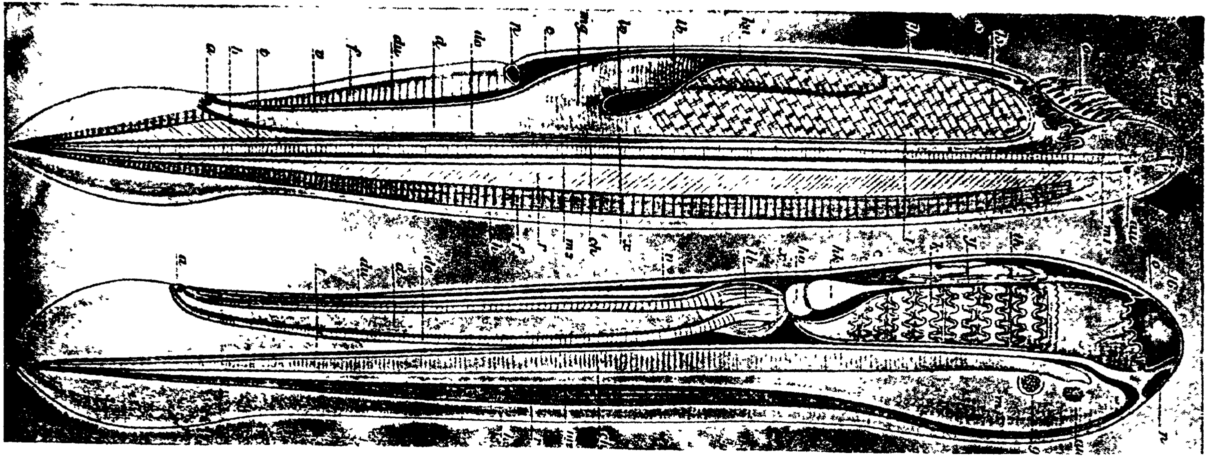


FIG. 242, Group IX.—Adult Amphioxus (above) (× 4), Larva Lamprey (below) (× 45).—*Au*, eye; *a*, anus; *b*, ventral muscles; *c*, mantle cavity; *ch*, chorda; *cl*, cloaca; *cs*, chorda-sheath; *d*, alimentary canal (gut); *do*, dorsal wall of gut; *du*, ventral wall of gut; *e*, ovary; *en*, endostyle; *f*, fin border; *g*, auditory vesicle; *h*, horny plate; *hd*, testicles; *hk*, ventricle of heart; *hv*, auricle of heart; *hz*, heart; *i*, ova; *k*, gills; *ka*, branchial artery; *l*, corium (cutis); *lb*, liver; lb^1, anterior end of liver; *lv*, hepatic vein; *m*, medullary tube; m^1, cerebral vesicle; m^2, spinal marrow; *ma*, anterior opening of m^2; *mb*, muscular ligaments; *mg*, stomach; *mh*, mouth cavity; *mp*, muscle plate; *mt*, mantle; *n*, nose; *o*, mouth; *p*, ventral pore; *q*, ejection opening (cloaca); *r*, dorsal muscles; *s*, tail fin; *sl*, sperm duct; *sm*, its aperture; *ss*, sense organs; *t*, aorta; *th*, thyroid gland; *u*, lateral canal of mantle folds; *v*, subintestinal vein; *x*, limit of branchial gut and hepatic gut; *y*, gullet groove.

brates. There is a striking similarity between Amphioxus and the larval Ascidian (Fig. 240) on the one hand and the larval lamprey on the other (Fig. 242).

GROUP IX.—ACRANIA

The Amphioxus represents the lowest (Acrania, headless) division of the Vertebrates. In Fig. 242 it is compared with a young lamprey larva. The chief characteristics which distinguish the Vertebrates or Craniata from the Invertebrates are (1) a dorsal medullary tube; (2) a notochord between this and the gut; (3) the division of the latter into branchial and hepatic gut; and (4) the internal segmentation or metamerism.

The Amphioxus is the only surviving member of the old acraniate division that arose from the more primitive pro-Chordata. All other Vertebrates belong to the Craniata—skull-animals—direct descendants of the Acrania.

GROUP X.—LAMPREYS

The lampreys (Fig. 242) fill a gap between Amphioxus and the true fishes. All the skull-animals are divided into Cyclostoma (round-mouthed), of which very few have survived (the lamprey being one), and Gnathostoma (jaw-mouthed).

Lampreys possess no bony skeleton and only a very rudimentary skull. The " backbone " of this creature (and its cousin the hagfish) *is* the notochord. Another significant point is that these animals have pairs of small cartilaginous plates arranged along the notochord on either side of the nerve-cord, thus foreshadowing the neural arches of the higher Vertebrates. The brain, at first a mere bulge of the forward end of this nerve-cord or " spinal marrow," develops later into the five cerebral vesicles characteristic of higher Vertebrates.

GROUP XI.—SHARKS

The Selachii or sharks (Fig. 243) possess many primitive features, among which is a cartilaginous skeleton.

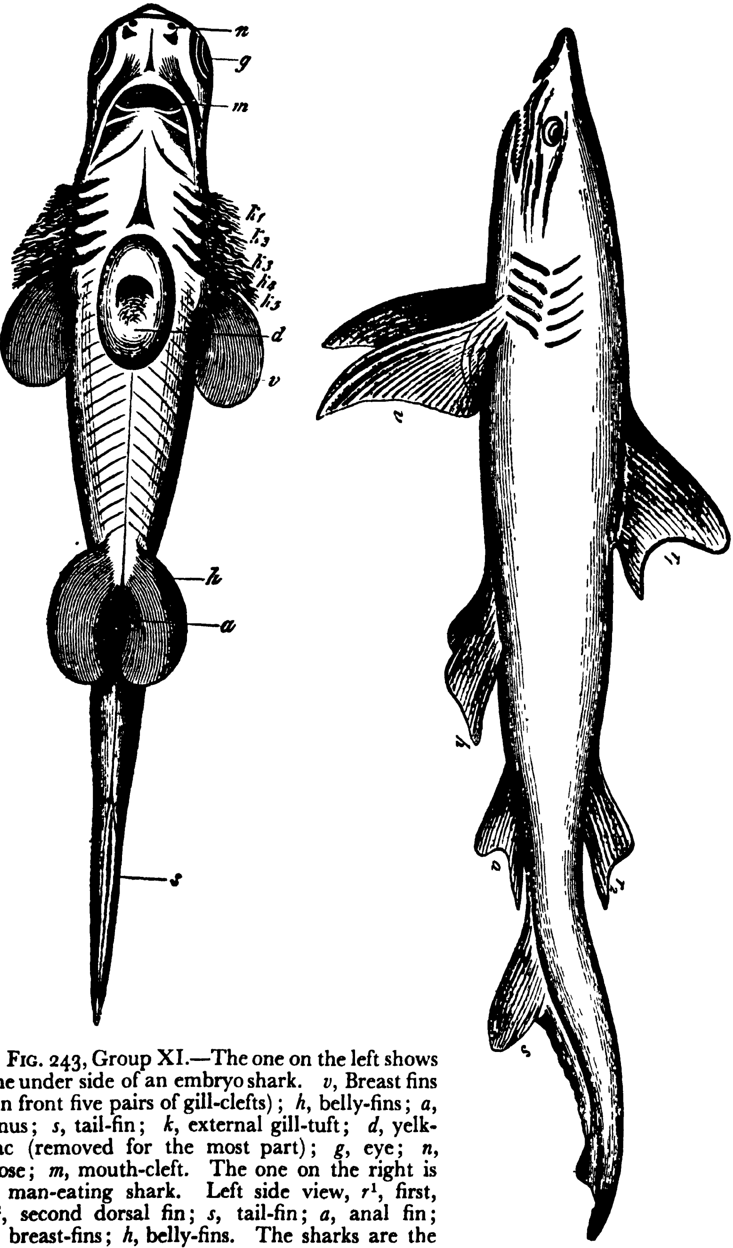


FIG. 243, Group XI.—The one on the left shows the under side of an embryo shark. *v*, Breast fins (in front five pairs of gill-clefts); *h*, belly-fins; *a*, anus; *s*, tail-fin; *k*, external gill-tuft; *d*, yelk-sac (removed for the most part); *g*, eye; *n*, nose; *m*, mouth-cleft. The one on the right is a man-eating shark. Left side view, r^1, first, r^2, second dorsal fin; *s*, tail-fin; *a*, anal fin; *v*, breast-fins; *h*, belly-fins. The sharks are the lowest of Elasmobranch fish.

GROUP XII.—CROSSOPTERYGIAN FISHES, OR FOSSIL GANOIDS

From the primitive fishes were developed the Ganoids (plated fishes), abundant as fossils. Some of these Ganoids are like sharks, others approach the Dipneusts (Fig. 244).

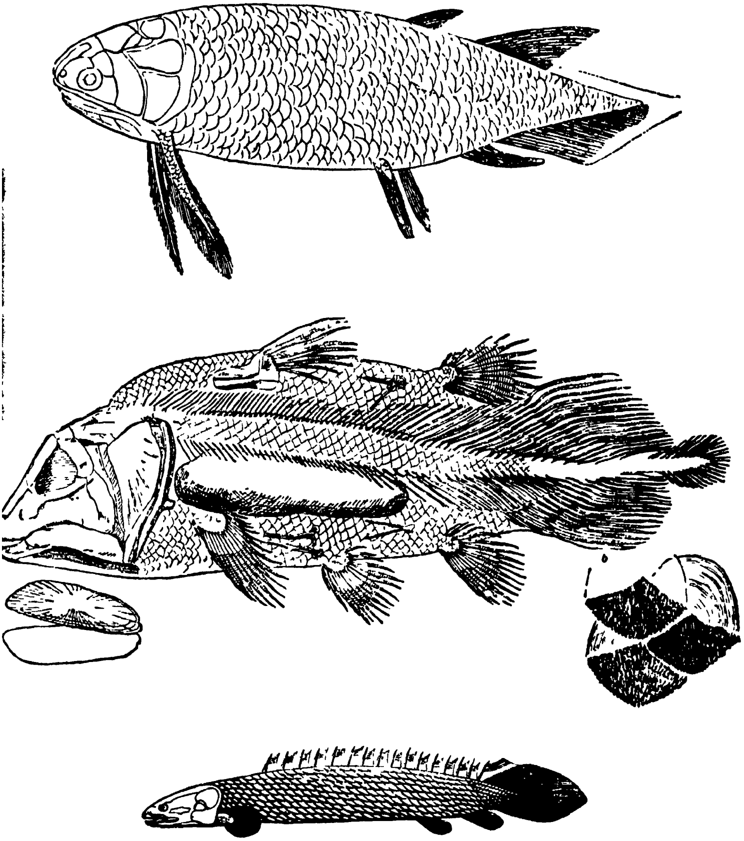


FIG. 244, Group XII.—The top one is a Devonian Crossopterygius. The middle one is a Jurassic Crossopterygius. *j*, Jugular plates; *b*, three ribbed scales. The bottom one is a living Crossopterygius—the Polypterus.

GROUP XIII.—DIPNEUST (DOUBLE-BREATHING) FISH

These double-breathing fish constitute the link between the former and the succeeding group—in short, they bridge the gap between water-breathers and air-breathers, between aquatic and land animals (Fig. 245).

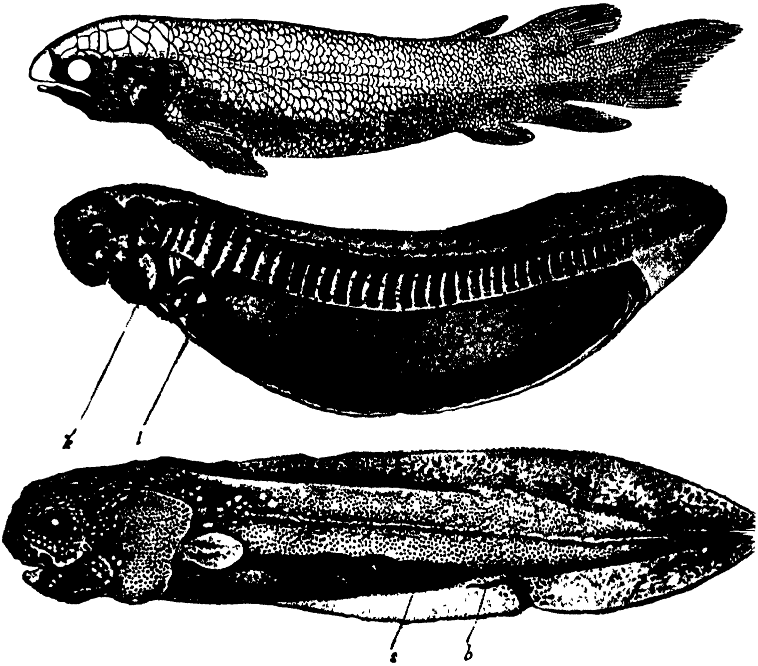


FIG. 245, Group XIII.—The top one is a fossil, the middle a young Ceratodus, shortly after issuing from the egg; the bottom Ceratodus a little older. *s*, Spinal fold of gut; *b*, rudimentary belly-fin.

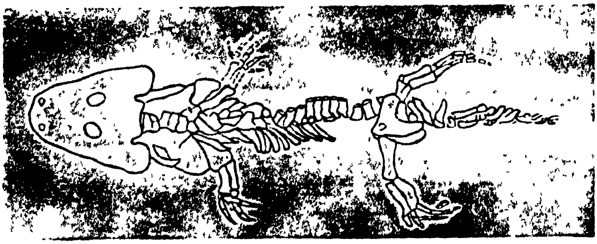


FIG. 246, Group XIV.—Skeleton of Actinodon, a very early Amphibian, from the Permian strata.

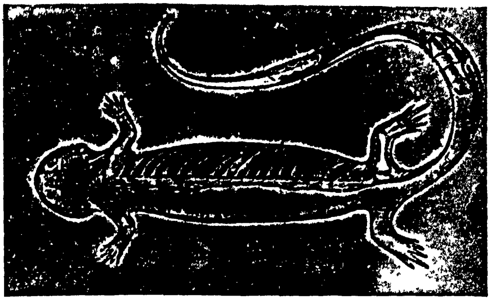


FIG. 247, Group XIV.—Keraterpeton, from Lower Permian.

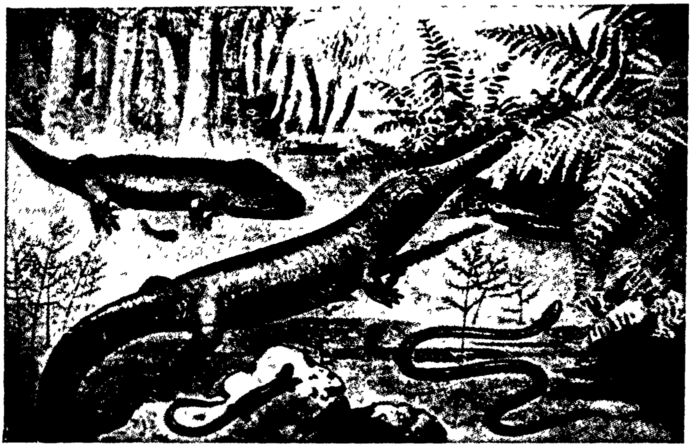


FIG. 248, Group XIV.—Group of Amphibians of the coal forest period. The big one in the centre is Archægosaurus; the one above Actinodon; the one immediately below Keraterpeton; the snake-like creature is the Dolichosoma; the head peeping out of the ferns is that of Loxomma.

GROUP XIV.—AMPHIBIANS

Amphibians are the first terrestrial animals. From the roof-headed ones (Stegocephala) came the reptiles (Figs. 246, 247, and 248).

GROUP XV.—REPTILES

The early reptiles (Figs. 249 and 250) gave off two side-branches, one for the pro-mammals, the other for the birds.

GROUP XVI.—PRO-MAMMALS

These are the primitive egg-laying mammals, the

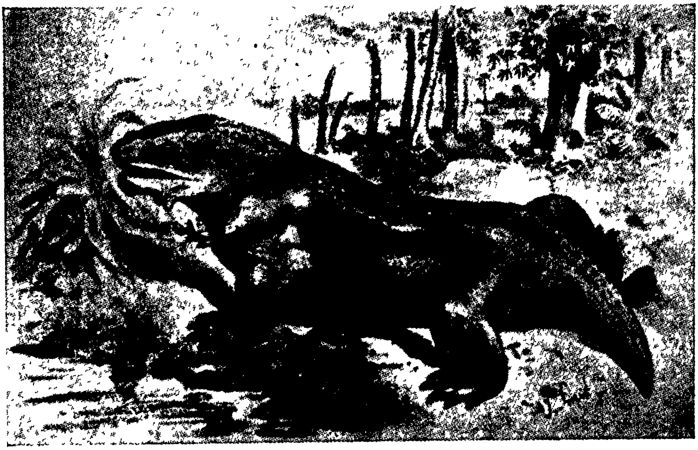


FIG. 249, Group XV.—The Pariasaurus (see Fig. 63) restored.

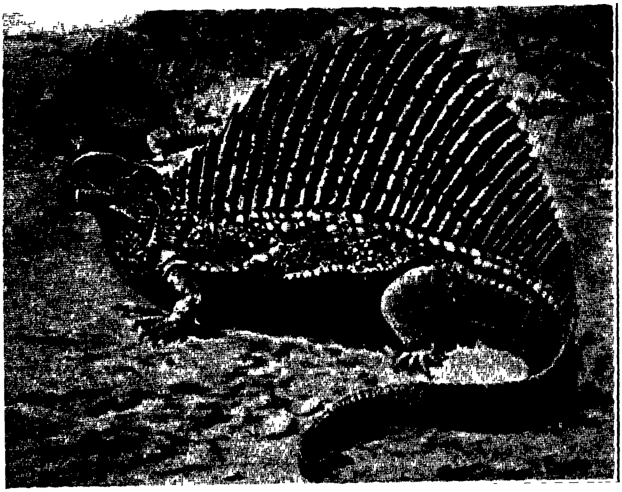
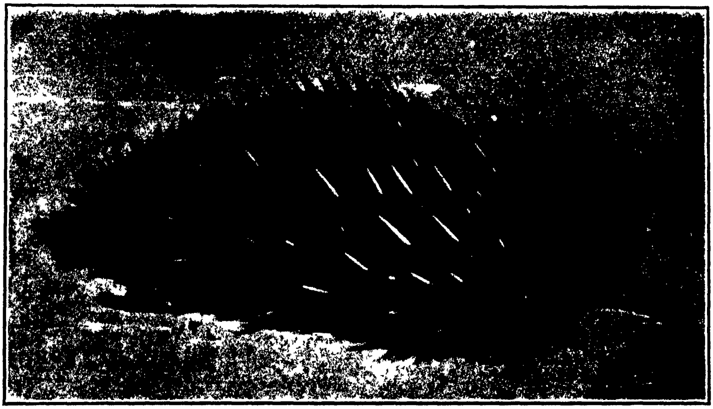


FIG. 250, Group XV.—Probable appearance of the Theromorph Reptile, Dimetrodon.



F. W. Bond.

FIG. 251, Group XVI.—*Echidna Hystrix*, the Australian Ant-eater.

FIG. 252, Group XVII.—*Tarsipes Rostratus*, a long-snouted phalanger of W. Australia, which has a prehensile tail and a prehensile tongue.

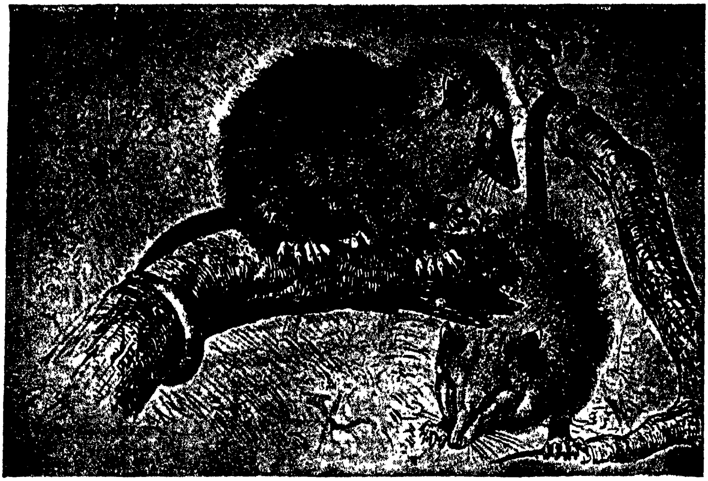


FIG. 253, Group XVII.—*Didelphys Marsupialis*, the common Opossum of S. America. It is three to five times larger than any other Opossum.

FIG. 254, Group XVIII.—Pen-tailed Tree Shrew.

Monotremes, that link reptiles with the higher mammals (Figs. 119 and 251).

GROUP XVII.—THE MARSUPIALS, OR POUCHED ANIMALS

Marsupials are a very ancient and widely distributed group. They were certainly present in Cretaceous–Eocene times among the *Multituberculata* and *Plagiaulacidæ*, though what part, if any, they played in the evolution of modern mammals is uncertain (Figs. 252 and 253).

GROUP XVIII.—INSECT-FEEDERS (INSECTIVORS)

The consensus of opinion among zoologists favours the view that one of the earliest mammalian ancestors of man *and* ape was an Insectivorous animal of the tree-shrew type (Figs. 254, 255).

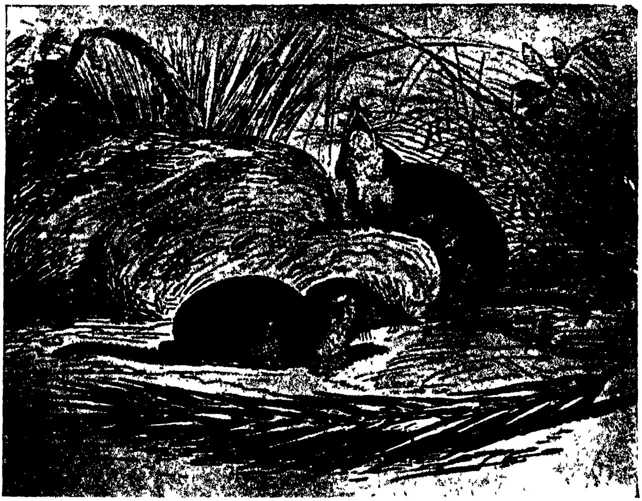


FIG. 255, Group XVIII.—The *Myogale*, or Desman (Musk Shrew). Connects the moles with the shrews.

F. W. Bond.

FIG. 256, Group XIX.—*Microcebus*, the Dwarf Mouse Lemur.

F. W. Bond.

FIG. 257, Group XX.—*Alouatta*, the Red Howler of S. America.

GROUP XIX.—LEMURS

These creatures are, so to speak, monkeys in the making, hence one of their names, " half-apes " (Fig. 256).

GROUP XX.—PLATYRRHINE MONKEYS

The flat-nosed monkeys are found only in America (Fig. 257).

GROUP XXI.—CATARRHINE MONKEYS

The down-nosed monkeys and apes belong to the Old World (Figs. 258–261). They are more nearly related to man than the flat-nosed monkeys of the New World. The difference between the lowest monkey and the highest man-like ape, the chimpanzee, is greater than the difference between the highest ape and the lowest man.

FIG. 258, Group XXI.—*Cynopithecus Niger*, the Celebesian Black Ape.

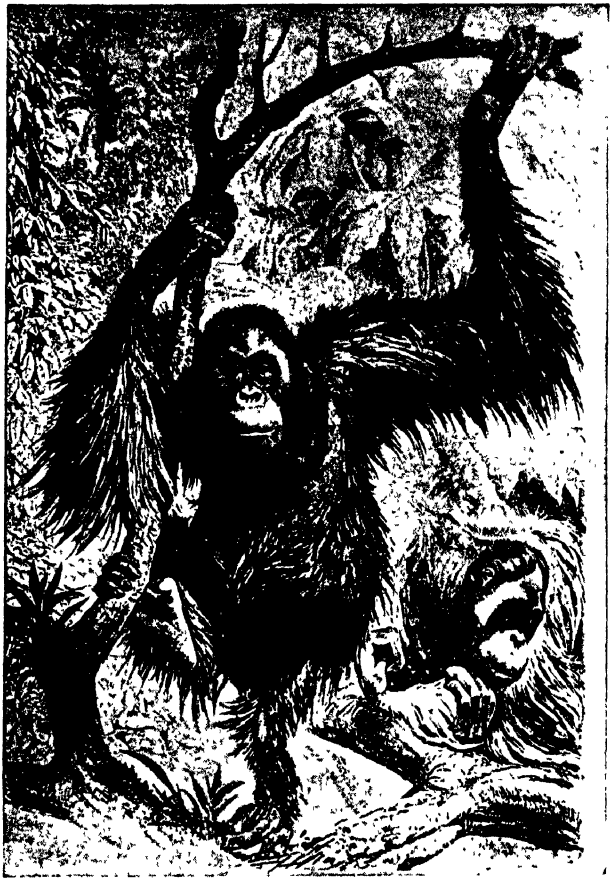


Fig. 259, Group XXI.—*Simia Satyrus*, the Orang-Utan of Borneo and Sumatra. This "Man of the Woods" constructs a temporary shelter in the trees.

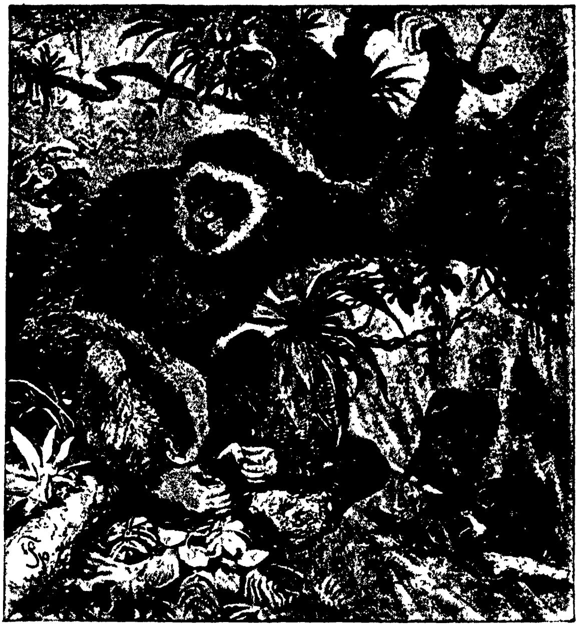


FIG. 260, Group XXI.—*Hylobates Lar*, the White-handed Gibbon of the upland forests of Malay.

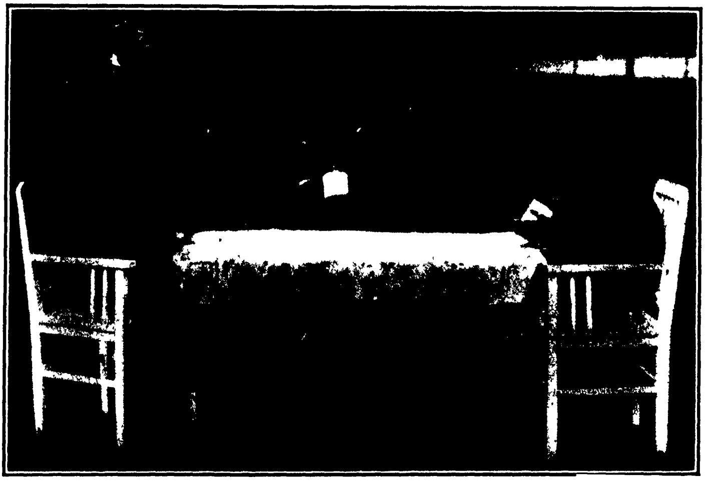


FIG. 261, Group XXI.—A Tea-party at the London Zoo. The Chimpanzee (*Anthropopithecus*), the most teachable of all the man-like apes.

FIG. 262.—Parental Love.

The gentle yet mighty power that protects and preserves the higher types of life.

(From *Creation by Evolution*, ed. by Frances Mason.)

The Family Tree of Man (Fig. 263) is given to show some of our *nearer* relations. In studying the human pedigree by means of this genealogical tree it should be borne in mind that the names on the trunk represent the type-group of animals through which man has evolved, and they are necessarily *fossils*, while the names towards the ends of the branches that reach the top line stand for *living animals.* Branch lines that fail to reach the top represent extinct apes, men, and men-apes.

It is hardly necessary to say that the diagram does no more than give a bird's-eye view of man's genealogical tree since the family of the first primitive jumping-shrew mammaloid of the late Cretaceous days began to split up into the many branches leading to existing mammals.

Fig 264 illustrates in diagrammatic form the Prehistoric Culture Periods and their relationship to the Geologic, Humanoid, and Historic periods.

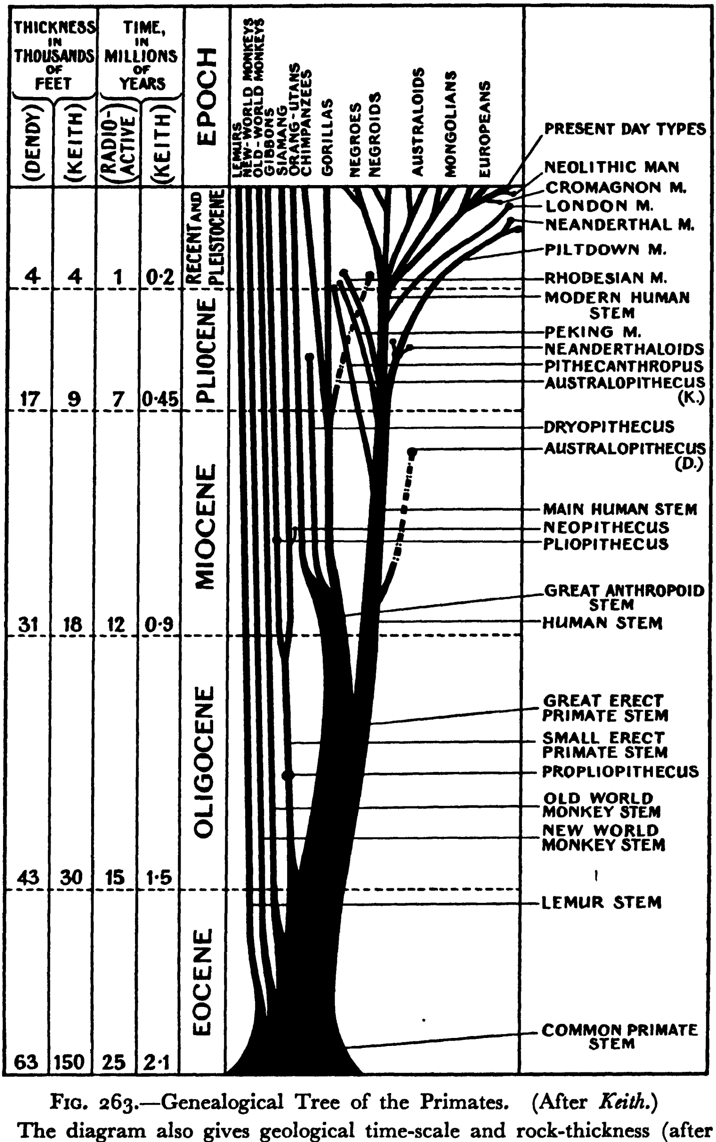


FIG. 263.—Genealogical Tree of the Primates. (After *Keith.*)

The diagram also gives geological time-scale and rock-thickness (after authorities stated). Australopithecus (K.) and (D.) indicate the positions of this South African (Taungs) Ape-man with Australoid features assigned by Professors Keith and Dart respectively.

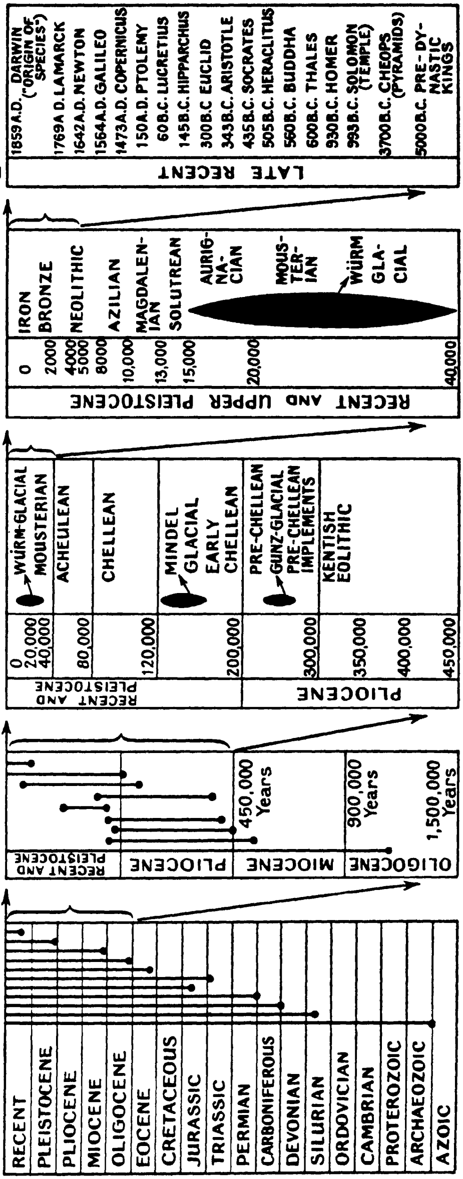


FIG. 264.—Diagram to illustrate Prehistoric Culture Periods and their relation in time to Geologic and Humanoid Periods on the one hand, and to the Historic Period on the other. (The Cultures and Humanoid Time Scales are after *Keith*.)

APPENDIX A

THE PROGRESS OF SCIENCE TILL NEWTON

IT will be useful to furnish a few particulars of some of the illustrious men whose lives have been devoted to the study of Evolution and of the sciences connected with it.

Some 600 years before Christ there were men of the Ionian race who studied the origin of the universe, notably Thales and Anaximander the Milesian. Anaximander (611–547 B.C.) was the first teacher of the doctrine of Abiogenesis—*i.e.* the origin of living things from inorganic matter. Heraclitus, Empedocles, Democritus, and Anaxagoras developed some surprising anticipations of the Evolution idea.

EMPEDOCLES of Agrigentum (495–435 B.C.) held "first, that the development of life was a gradual process; second, that plants were evolved before animals; third, that imperfect forms were gradually replaced by perfect forms; fourth, that the natural cause of the production of perfect forms was the extinction of the imperfect."

DEMOCRITUS (470?–362? B.C.) was the founder of the Atomistic philosophy, the precursor of materialism.

ARISTOTLE (384–322 B.C.) may be said to have created Natural History or Ecology, in his *Physics* and *The Natural History of Animals.* He made many original observations upon plants and animals and was the first to conceive of a genetic series, and of a *single chain* of evolution, from polyp to man. He rightly conceived of life as the function of the organism, not as a separate principle; he anticipated Harvey's doctrine of Epigenesis in embryonic development, he fully perceived the forces of hereditary transmission, of the prepotency of one parent or stock, and of Atavism or Reversion. He saw the fundamental difference between animals and plants, and distinguished the organic or living world from the inorganic or lifeless world.

LUCRETIUS (95–52 B.C.) in his grand poem, *De Rerum Natura,* stands forth as an early poet of Evolution. With Empedocles and Epicurus he held a survival-of-the-fittest view of life. Being a Rationalist, he had no place for Centaurs and Chimæras in his history of creation and rejected the teleological for the mechanical conception of nature.

Ptolemy lived at Alexandria about 150 A.D. He was the last of the great Greek astronomers. He published the *Almagest* (the Greatest), in thirteen books, in which were collected his own discoveries and theories as well as those of his predecessors, among whom was the famous Hipparchus (160 B.C.). This book became the astronomical " Bible " of the Middle Ages. It endeavoured to square a complicated system of cycles and epicycles with observed facts. Ptolemy's great error was his belief that the earth had no motion and was the centre of the heavens. About fourteen centuries elapsed between the publication of the *Almagest* and the death of Copernicus (1543), and during this long period the greatest minds struggled to understand the motions of the heavenly bodies on Ptolemy's wrong theory that the stars and sun revolved around the earth. His theories acquired an authority inconceivable to us.

Copernicus (1473–1543) was born in the little town of Thorn in Russia. He taught the then revolutionary doctrine that it was the earth that moved while the sun and stars were at rest. On this account, about 1531, he was ridiculed on the stage and described as a fool by Luther for going against the Bible, while Melanchthon hinted that his opinions should be suppressed. Publication of his great work, *The Movements of Celestial Bodies*, was only completed in time for the book to be placed in his hands on the day of his death, so that he was beyond the reach of the subsequent fury of his persecutors. From his day onwards it had to be admitted that the earth was but a somewhat insignificant planet rotating on its axis and revolving around a central sun which we now know is 332,000 times more massive than the earth.

Galileo Galilei (1564–1642), the great Italian astronomer, accepted and improved upon the system of Copernicus and in consequence suffered great persecution at the hands of the Roman Catholic Church. He was finally examined by the Inquisition on June 21, 1633, under threat of torture and " was convicted of believing and holding the doctrines—false and contrary to the Holy and Divine Scriptures—that the sun is the centre of the world, and that it does not move from east to west, and that the earth does move and is not the centre of the world." He was required to " abjure, curse, and detest the aforesaid errors" on his knees and was condemned to the "formal prison of the Holy Office" during the pleasure of his judges. Finally, he was ordered to repeat the seven penitential psalms once a week for three years. It is said that when Galileo rose from his knees after his enforced perjury he stamped his foot and whispered to a friend, "*Eppur si muove*" ("Nevertheless, it (the earth) *does* move"). It has become "fashionable" of late to deny the story; for instance, the Hon. Bertrand (Lord) Russell says: "It is not true that, after reciting this abjuration, he muttered: '*Eppur si muove.*' It was the world that said this—not Galileo." (*The Scientific Outlook*, 1931.) Old and blind, Galileo died January 8, 1642, nearly seventy-eight years of age.

Though Copernicus had found the sun to be the correct centre of our system, he still made use of "the epicycles and eccentrics of the Greeks," and it was Kepler (1571–1630) to whom we are really indebted for their rejection. He will be for ever famous for the working out of his three planetary laws:

(1) Planets move in ellipses.
(2) The straight line joining the centres of the sun and planet, the "radius vector," sweeps over equal areas in equal times.
(3) The squares of the periodic times of the planets are proportional to the cubes of their distances from the sun.

Isaac Newton (1642–1727) accomplished most remarkable work in astronomy, optics, and pure mathematics. He stands forth as one of the greatest men of all time. We are here concerned with his brilliant discovery of the Law of Gravitation, which states that the attraction between two particles of matter is directly proportional to the product of their masses and inversely proportional to the square of their distances apart.

Other astronomers had toiled to show *how* the heavenly bodies moved; Newton discovered *why*. He held that the centre of the sun is the centre of gravity of the solar system but not of the universe; that it is at rest relatively to all the planets, satellites, etc. in the solar system, but not in relation to the stars and other heavenly bodies of the universe.

APPENDIX B

SOME RECENT WORKERS IN THE FIELD OF EVOLUTION

ADAMI, Dr. J. G., C.B.E., F.R.S. B. Manchester, 1862; d. 1926. Pathologist. His *Medical Contributions to the Study of Evolution* shows how deeply the purely medical sciences and surgical arts are indebted to Evolution.

ALLEN, CHARLES GRANT (b. Kingston, Canada, Feb. 24, 1848; d. 1899), was a remarkable combination of scientist and novelist. He wrote *The Evolutionist at Large*, *Vignettes from Nature*, *Charles Darwin*, and *The Evolution of the Idea of God*, the last-named being undoubtedly his greatest achievement.

ARRHENIUS, SVANTE. Swedish chemist and astrophysicist. B. Feb. 19, 1859; d. 1927. He was one of the first astronomers to stress the importance of the disaggregative effects of light-pressure and radiation-pressure on minute particles of matter in counterbalancing the aggregative effects of gravitation. Pub. *Worlds in the Making*, *Life of the Universe*—both classics in stellar evolution.

BAER, K. E. VON (1792–1876). Russian biologist; discovered the ovum of mammals in 1827; he also described the three primary germ-layers—ectoderm, mesoderm and endoderm—in the vertebrate embryo. He enunciated "von Baer's law," that development is a progress from the general to the special—a law that profoundly influenced Herbert Spencer's work.

BATHER, Professor FRANCIS ARTHUR, F.R.S. President of the Geological Society. B. 1863. Pub. *Record of the Rocks*. Has written numerous technical papers on geological and biological questions pertaining to fossil invertebrates, especially the Crinoids.

BERNARD, CLAUDE (1813–78). French physiologist of the mechanistic school. His famous *Phenomena of Life* exhibited a revolutionary advance of thought.

BLAND-SUTTON, Sir JOHN. Pathologist and gynecological surgeon. B. Enfield, 1855. One of the pioneers who boldly carried the principles of Evolution into the domain of medicine and surgery.

Pub. *Evolution and Disease, Man and Beast in Eastern Ethiopia.*

Bon, Gustave Le. Has made a special study of the "mass"—or "herd-mind." Pub. *Evolution of Matter, Evolution of Forces, Psychology of the Crowd,* all evincing a mechanistic outlook on life.

Bose, Professor Sir Jagadis Chandra, F.R.S. B. Nov. 30, 1858. Pub. *Response in the Living and Non-living, Life-movements in Plants, Plant-response.*

By means of his personally-devised and exquisitely sensitive electrical apparatus he has proved that "irritability," that is, response to environmental stimuli, is not the prerogative of animals and plants, but extends into the so-called dead inorganic world. He has shown that metals, for example, not only get "fatigued" if "over-worked," but can be "poisoned," or thrown into a "non-irritable" and inert condition wherein their normal response to stimuli fails.

Buffon (1707–1788) may be called the naturalist who laid the basis of modern Evolution in zoology and botany. He first pointed out, on a broad scale, the mutability of species in relation to changes of environment.

Burbank, Luther. Botanist and naturalist. B. Lancaster, Mass., March 7, 1849; d. April, 1926. Pub. *New Creations in Fruits and Flowers, How Plants are trained to Work for Man.* By his hybridization, grafting and crossing experiments generally, he evolved numerous new fruits and flowers, and by ruthless elimination of the unfit (for his purpose) produced stoneless plums, thornless cacti, rapid-growing walnut trees. He also increased the scent of many flowers. This "Wizard of fruits" was a firm believer in the transmission of acquired characters.

Clodd, Edward. B. Margate, July 1, 1840; d. 1930. Folk-lorist. A pioneer writer on Evolution, who devoted a great part of his life to the exposure of superstition in its several guises. Pub. *Childhood of the World, Childhood of Religions, Story of Creation, Story of Primitive Man, T. H. Huxley, Primer of Evolution.*

Cope, Professor E. D. One of the leading comparative anatomists of America. Has written extensively on Evolution. Pub. *Primary Factors of Organic Evolution.*

Crile, Professor **George** W. B. 1864. Has made a special study of the organs of internal secretion, the Hormone or Endocrine Glands, and the part they play in the manifestation of the emotions—fright, joy, anger, love, etc.

Crookes, Sir **William**, F.R.S., O.M. (1832–1919). He perfected the Geissler vacuum tube and investigated the properties of the *Kathodal Glow* and the dark space (now known as Crookes' dark space), and so paved the way to the discovery of X-rays and ultra-gaseous physics and to the subsequent disintegration of the atom by J. J. Thomson, Rutherford, Soddy, and others. Discoverer of the element Thallium. Pub. *Genesis of the Elements.*

Cuvier, **Georges** (1769–1832). Though one of the greatest geologists of the age he rejected the theory of Evolution, and being on the side of conventionalism and authority, dominated zoological science for half a century.

Darwin, **Charles**. B. Feb. 12, 1809; d. April 19, 1882. On November 24, 1859, occurred what may fairly be called the most important event in the history of biology—the publication of his *Origin of Species.* This work converted the whole scientific world to the general doctrine of transformism within twenty years. The theory of Natural Selection, the Survival of the Fittest, or the preservation of favoured races in the struggle for life, was first conceived by Darwin in 1838, but it was not till 1858 that public announcement of it was made simultaneously by himself and Wallace. Both naturalists had, however, been anticipated by Dr. W. C. Wells in 1813, and by Patrick Matthew in 1831, though neither Darwin nor Wallace knew of the fact. But whatever others may have discovered it was Darwin who first convinced men of the truth of Evolution. In 1842 he went to live at Down House, Downe, near Beckenham in Kent, where he patiently continued his researches into the evolution of animals and plants. Thanks to an appeal for funds for the preservation of Down House made in the course of his Presidential Address to the British Association on August 31, 1927, by Sir Arthur Keith, and the prompt and generous response thereto by Mr. (now Sir) Buckston Browne, Down House has become the property of the nation, and it is now possible for all to see Darwin's study, garden, and grounds almost as they were when he was present. It may be truly said of this greatest of men that he altered the centre of gravity of thought and " lifted empires off their hinges."

DARWIN, ERASMUS (1731–1802), was the grandfather of Charles Darwin, and was born at Elton, near Newark. In his *Zoonomia* he advanced the view that all animals originated from some one specially-created organism, whose descendants were permitted to evolve by means of *adaptation to environment*, *elimination of the unfit*, and the *transmission of acquired characters*. He thus anticipated Lamarck, Spencer, and his illustrious grandson. However, in his scheme of Evolution, Natural Selection appears to be entirely overlooked.

DENDY, ARTHUR, F.R.S. Late Professor of Zoology, University of London. Pub. *Outlines of Evolutionary Biology*. It was Dendy who first drew attention to what he termed " Momentum in Evolution," a principle whereby some species are carried to destruction owing to the fact that certain organs continue to develop until they not only pass the point of maximum utility and cease to be useful but become a positive encumbrance and danger to their owners. Cases in point are the unwieldy antlers of the Irish Elk, the long teeth of Machærodus, the heavy carapace of the giant Armadillo, and the massive tusks of extinct elephants. The enormous beak of the Hornbill will probably bring about this bird's downfall in life's race.

EDDINGTON, Sir ARTHUR, F.R.S. B. 1882. He was the first astronomer to put Einstein's prediction of the bending of light when passing through a strong gravitational field to the test, and thereby to confirm it. With Lemaître and de Sitter, Eddington believes the Universe to be finite and expanding in space like a soap-bubble that is being blown by a child. Whereas the Universe had, so he thinks, in the past a diameter of the order of 14,400 million, million, million miles, its diameter now is some 24,000 million, million, million miles. Eddington has shown that the luminosity of stars is directly related to their mass. He has, *inter alia*, calculated the central temperature of our sun as being about 32,000000°. He is said to be one of the few who have made an exhaustive study of Einstein's theory of Relativity. Pub. *Man's Place in the Universe*, *Stellar Movements and the Structure of the Universe.*

EINSTEIN, ALBERT. German scientist. B. 1878. When only sixteen years of age he read a mathematical paper which astonished scientists by its profundity of thought. He published his first work on Relativity in 1905 while attached to a Swiss University, and his great one, which has caused all the furore, ten years later while working in a laboratory in Berlin. Einstein is not the " inventor " of Relativity, for this has been a subject of philosophic discussion for many years, but his is the credit for having made the theory, *in certain instances*, square with observed facts of nature. For example, by it he has accounted for the puzzling annual shift of the perihelion of Mercury's orbit. Take again the question of *gravitation* and *inertia*. In a vacuum all bodies, whatever their mass, behave similarly as regards inertial and gravitational forces, for both are due to a common cause—acceleration. A person in a fixed closed chamber in a gravitational field can sense all phenomena due to gravity, but should the whole chamber fall through space with acceleration normal to the gravitational force, he, as well as all other objects with him, *would have no weight*. A book released from the hand would remain poised in the air. *Action at a distance*, conventionally explained as the " pull " between two bodies in space such as our moon and earth, has always been a thorn in the side of physicists. No scientist has ever really believed in the existence of such a " pull " ; indeed, a " pull " across nothing is inconceivable. Le Sage's " push " through impact of countless ultramundane corpuscles was at any rate an explanation of gravitation that could be intellectually grasped. The Relativity theory claims to give an explanation of "gravity" without resort either to "pull" or "push" by postulating as the cause of the gravitational movement towards one another of two bodies "an inherent order of nature in space"! The safer and more truly scientific attitude is to reserve judgment upon some of the conclusions recently enunciated by those scientists who have identified themselves with Relativity, and to decline to be waved about by every wind of doctrine. Brilliant discoveries were made and predictions fulfilled on the assumption that the earth was a finitely bounded flat plane; also on the assumption that it was a sphere around which a starry vault revolved; and again on the assumption that it was an almost infinitesimal speck amid an infinite number of other bodies scattered through an eternally existent and infinitely extended space. Hence the argument that because predictions based on some hypothesis prove correct, therefore the hypothesis must be true, is entirely fallacious. Inferences as to the Cosmos that are drawn from mathematics with its manipulations of abstract symbols such as zero, plus and minus infinities, and the square root of minus one, which represent no possible concretes, are necessarily suspect. The assumptions of the neo-Relativists would, in many instances, appear to be, as the physiologist Dercum has suggested, but evidence of the vagaries of human cerebral neurone activities. Some of such assumptions border on the fantastical—*e.g.* that a planetary electron can jump from one orbit to another in NO TIME; that the radius of an electron can be $\frac{1}{5{,}000000{,}000000}$ centimetre *and* infinite in extent; that certain faint and apparently very distant nebulæ, *e.g.* M. 83 and h. 3433, are in reality the two nearest nebulæ to us, M. 31 and M. 33, "seen the long way round space"—that is, that we see them face to face when looking at M. 31 and M. 33, but that we see the back of them when looking at M. 83 and h. 3433! Mathematics, in the hands of Pythagoras, Einstein, Eddington, and Jeans, can be made to prove, apparently, almost anything; but when, as ultimately we must, we come down to basic facts we know, despite all the mathematician's assurances to the contrary, that the hare does catch up with the tortoise!

The great work of Einstein has been the development and correction of that of Newton. It was on May 19, 1919, during the solar eclipse, that one of Einstein's predictions—the observable deflection of light by large cosmic masses—was put to the test and confirmed. Einstein, so far as one can gather, conceives of the Universe in pure space-time terms as a four-dimensional continuum in which TIME is the *fourth dimension*, SPACE accounting for the primary three extensions. The masses of matter scattered throughout space become, in Einstein's view, evanescent crumplings in a four-dimensional continuum!

FLEURE, HERBERT JOHN. Professor of Geography at Manchester University. B. Guernsey, 1877. Pub. *Survival of Palæolithic Types*, *Evolution of European Races.* He has made a special study of the glacial periods and Palæolithic men, subjects specially dealt with in *Apes and Men*, *Hunters and Artists*, *Peasants and Potters*, all written in conjunction with Harold Peake.

GALTON, FRANCIS, F.R.S. (1822–1911). A cousin of Charles Darwin. He originated the method of identification by means of finger-prints. As Mendel had done for plants, Galton worked out the heritage proportions present in animal offspring. He showed that the two parents contribute between them *on the average* one-half of the total heritage, the four grandparents a quarter, the eight great-grandparents an eighth, the sixteen great-great-grandparents a sixteenth, and so on, the sum of the ancestral conditions being expressed by the series

$$\tfrac{1}{2} + (\tfrac{1}{2})^2 + (\tfrac{1}{2})^3 + (\tfrac{1}{2})^4 \;.\;.\;.\;.\; \text{etc.} = 1.$$

Thus every individual receives on the average one-quarter's heritage from the father, one-quarter from the mother and one-half from all its ancestors. This ancestral half (which theoretically extends back to the dawn of life) often swamps the parental half, and such counteraction is known as *Galton's Law of Filial Regression.* " It is the heavy weight of this mediocre ancestry," as Karl Pearson puts it, "which causes the son of an exceptional father to regress towards the general population mean; it is the balance of this sturdy commonplaceness which enables the son of a degenerate father to escape the whole burden of the parental ill. Among mankind we trust largely for our exceptional men to extreme variations occurring among the commonplace. . . . If we could remove the drag of the mediocre element in ancestry, were it only for a few generations, we should sensibly eliminate regression or create a stock of exceptional men."

GEDDES, Sir PATRICK. Biologist. B. 1854; d. April, 1932. Contributed very largely to the science of evolutionary biology. Pub. in conjunction with Sir J. A. Thomson, *Evolution of Sex*, *Evolution and Sex*, *Sex*, *Biology*, *Life*.

GEGENBAUR, KARL (1826–1903), is described by Haeckel as "the comparative anatomist who surpassed all other experts of this science, in the second half of the nineteenth century." His great work is *The Comparative Anatomy of the Vertebrates*.

He showed that the nerves proceeding from the base of the brain are modifications of spinal nerves. It was Gegenbaur who first suggested that the wings of insects originated as modifications of the leaf-like tracheal gills. His theory presents certain difficulties, but none of them is of serious weight.

GOETHE, JOHANN WOLFGANG (1749–1832), the great German poet, was a keen supporter of Evolution. He introduced the term "morphology," to which science he made important contributions.

He recognized the importance of vestigial organs, and correctly predicted the presence of a premaxilla in man—the absence of that bone in the *adult* human skull being hitherto considered as distinctively separating man from the other Primates!

GREGORY, JOHN WALTER, F.R.S. Late Professor of Geology, University of Glasgow. B. Jan. 27, 1864. Has made many original researches into the geology of the Alps, and published numerous technical papers on geology.

GREGORY, Sir RICHARD, F.R.A.S., D.Sc. B. Bristol, Jan. 29, 1864. Emeritus Professor of Astronomy, Queen's College, London. Editor of *Nature.* Revised Huxley's *Physiography*, and has written extensively on that subject.

HAECKEL, ERNST. B. at Potsdam, 1834; d. 1919. One of the greatest Evolutionists and the first German to accept the discovery of Darwin, he did more than any one in Germany to demonstrate its truth. He was the first modern zoologist to attempt the classification of animals on a frankly evolutionary basis, and to him we owe the terms "phylogeny" and "ontogeny," "cœnogenesis" and "palingenesis," and the fruitful gastræa theory, according to which the gastrula is the ancestral form of all the Metazoa. Among his many works are *The Natural History of Creation*, *The Evolution of Man*, *The Riddle of the Universe*, and *The Wonders of Life.*

HARVEY, WILLIAM (1578–1667). Physician and physiologist. Discovered the Circulation of the Blood.

HELMHOLTZ, VON (1821–1894). Distinguished German physicist; discovered the *Conservation of Energy* in 1847.

HOOKER, Sir JOSEPH DALTON. B. at Halesworth, Suffolk, 1817; d. 1911. A great botanist who added considerably to our knowledge of the distribution of plants. He was director of Kew Gardens for twenty years, and as President of the British Association in 1868 supported the views of Darwin on Evolution.

HUXLEY, JULIAN. Zoologist. B. June 22, 1887. Grandson of Thomas Huxley. Past Professor of Zoology, King's College, London. Lecturer in Zoology, King's College, London. Mr. Huxley has written and lectured widely on evolutionary subjects. Pub. *Individual in the Animal Kingdom*, *Progress in Evolution.*

HUXLEY, LEONARD, LL.D. B. Dec. 11, 1860. Son of Thomas Huxley. His *Life of T. H. Huxley*, *Life of Charles Darwin*, and *Life of Sir Joseph Hooker* give one a delightful insight into the inner lives of these great Victorian Evolutionists.

HUXLEY, THOMAS HENRY (b. at Ealing, May 4, 1825; d. June 29, 1895), ranks as one of the foremost of the discoverers and teachers of Evolution. His wonderful ability, industry, fearlessness, and eloquence fitted him for the position of leader in the war against prejudice which broke out on the publication of Darwin's *Origin of Species.* Darwin used to say there were three judges by whose decisions he always abided—Lyell, Hooker, and Huxley.

JEANS, Sir JAMES, F.R.S. Astronomer. B. Sept. 11, 1877. Second Wrangler 1898. Pub. *Problems of Cosmogony, Astronomy and Cosmogony, Universe Around Us, Eos, The Mysterious Universe, The Stars in their Courses.* The last four works have made an especial appeal to the more thoughtful section of the reading public who evince a desire to know something about the structure and evolution of the Cosmos. Sir James Jeans sees the origin of our planets in discrete condensations occurring in an enormous cigar-shaped filament of gas torn out of our primordial sun by some passing huge star. He assumes a space-time finiteness to the Cosmos, a view that would appear to predicate its appearance in the past out of nothing. As regards the future, Sir James has resuscitated the theory (discarded by many cosmologists) known as "thermal extinction," the *Warmetod* or "heat-death" of Clausius, and as the "degradation of energy" of Kelvin. His general argument would appear to imply that since work in the human laboratory is invariably accompanied by degeneration of temperature to a lower and less available level, it must be accompanied by a similar degeneration throughout the cosmic laboratories. The entropy (or thermodynamic function) of the Universe is, he thinks (with Clausius), constantly increasing and tending to a maximum; the whole Cosmos is running down as regards work-availability, and a time must eventually arrive when it will be represented as a universally warm—neither hot nor cold—clod! Such view is obviously in contradiction to that idea of eternal continuity which is the foundation of the mechanical equivalent of heat, and it would, moreover, appear to ignore those forces in the Universe which maintain entropy at a constant mean. If we have read Sir James aright, it would also seem that he inclines to belief in a principle of *indeterminism* as regards, at any rate, the ultra-microscopic world of atoms. Such a view necessarily commits the holder to belief in spontaneous, that is self-caused, action; in other words, to belief in an effect without antecedent cause. The consistent student of evolution will do well to hold a watching-brief concerning some of the conclusions arrived at by this distinguished mathematician.

JORDAN, DAVID STARR. B. Jan. 19, 1851. American zoologist and professor of biology. Has contributed many writings upon Evolution. Pub. *Footnotes to Evolution*, *Evolution and Animal Life*, *Fishes*, etc.

JOULE, JAMES PRESCOTT. *See* Lavoisier.

KEITH, Sir ARTHUR, F.R.S. B. Feb. 5, 1866. Anthropologist. Conservator of Museum, and Hunterian Professor, Royal College of Surgeons; Rector, Aberdeen University; Past President of the Royal Anthropological Institute and of the British Association; Fullerian Professor of Physiology, 1917–1923. Sir Arthur has written profusely, both technically and popularly, on evolutionary subjects. For its outspokenness on the implications of Evolution, his notable address as President of the British Association in 1927 ranks with that of Tyndall at Belfast in 1874 and with the utterances of Huxley and Hooker at the Oxford meeting in 1860. Sir Arthur's numerous evolutionary works include *Introduction to the Study of Anthropoid Apes*, *Human Embryology and Morphology*, *Engines of the Human Body*, *Man's Origin*, *Antiquity of Man*, *New Discoveries relating to the Antiquity of Man*.

LAMARCK (1744–1829) was not only a distinguished zoologist and palæontologist, but may also be looked upon as the chief of the pre-Darwinian Evolutionists. In his *Philosophie Zoologique*, published in 1809 (the year in which Charles Darwin was born), he completely rejected the idea of the fixity of species, and endeavoured to explain the transformation of one form into another by the operation of known causes; of these he attached most importance to the principle of use and disuse, and he was a firm believer in use-inheritance.

Lamarck was violently attacked and ridiculed by the orthodox biologists, especially by Cuvier, and even Charles Darwin alluded disparagingly to his work. Lamarck was the first zoologist to formulate a definite evolutionary theory of descent, and though many of his assumptions are still debatable, the value of his immense contributions to Evolution has not yet received adequate recognition. He died poor, neglected, and blind.

LANKESTER, Professor Sir RAY, F.R.S., D.Sc. Zoologist. B. May 15, 1847; d. 1928. Professor of Zoology and Comparative Anatomy at the University of London, President of the British Association, Director of the Natural History Department of the British Museum, and Vice-President of the Royal Society. He carried out a vast amount of highly specialized research work in zoology, more especially on the invertebrate side. Edited the *Scientific Memoirs of Huxley* and translated Haeckel's *History of Creation.* Wrote widely for the general public on evolutionary topics, especially in his *Kingdom of Man*, *Extinct Animals*, *Science from an Easy Chair*, and *More Science from an Easy Chair.*

LAVOISIER, A. L. (1743-94). Chemist. Famous for his discoveries in connection with Oxygen (1775) and for his enunciation of the *Law of the Conservation of Mass* :—" *Matter is never created nor destroyed* in any chemical or other process." It was not until 1842 that Mayer, and quite independently in 1847 von Helmholtz, discovered the *Law of the Conservation of Energy.* By energy is meant capacity to do work, that is, ability to effect a change. Energy appears in many guises: potential—kinetic—heat—light—electric—and chemical energy. A definite quantity of energy is always a product of two factors: a *capacity* factor (length, volume, mass, caloric) and an *intensity* factor (weight, force, pressure, temperature, electromotive force). The types are transformable one into another, electrical into heat and so on, but a given quantity of one form is always strictly equivalent to a definite quantity of another form. These laws were clinched, so to speak, in 1843, when Joule made his great discovery of the *Mechanical Equivalent of Heat.* He proved that a definite amount of work produced a definite amount of heat. He showed, for example, that the fall through a distance of 772 feet of a pound weight sets free a quantity of mechanical energy that will raise the temperature of a pound of water 1° Fahrenheit. Finally, M. Carnot and M. Hirn reversed the process and demonstrated that *one degree Fahrenheit added to the temperature of a pound of water can perform work equivalent to raising a weight of* 1 *lb. to a height of* 772 *feet.*

Some people seem to have jumped to the conclusion that modern physics disproves the Laws of the Conservation of Mass and of Energy. It does nothing of the kind, despite its resolution of " matter " (in the familiar forms that act on our sense-organs) into hypothetical entities, " electrons " and " protons," and despite the possibility and even the probability that these electrons and protons are further transformable into ENERGY. The general principles of the Conservation of Mass and Energy hold as good to-day as when Lavoisier, Mayer, and Helmholtz first enunciated them. Our conceptions of the fundamental nature of " matter " and " energy " have, no doubt, undergone radical change, but the one solid fact remains that the sum-total of matter-energy in the Cosmos is a constant quantity—uncreatable and indestructible. This does not mean that " matter," or " energy," as familiar to us, is uncreatable and indestructible, but simply that where one is " created " the other is " annihilated "; indeed they are, so modern physicists assure us, convertible. Under the tremendous temperatures and pressures in the interior of certain stars some of the planetary electrons within the atom are forced into orbits nearer and nearer to the central proton until, finally, they coalesce, and the negative charge of the former and positive charge of the latter are neutralized. This cancelling out involves, however, utter disaster to the individualities of electron and proton, for they disappear as such—their place being taken by *radiations* or *quanta* of exceedingly short wave-length and excessively high energy. Such radiation possesses *weight*, that is, *mass*, just as truly as a cartload of bricks, and, consequently, nothing is lost in the transaction. The loss of mass on the part of the incandescent star through destruction of its crude matter about the centre reappears as an increase of mass amid the interstellar spaces.

Linnæus (1707–78), the famous Swedish naturalist, wrote the *Systema Naturæ*, which was the turning-point in modern zoology and botany. He was an industrious collector of facts, and wrought important changes in classification. His ambition was to arrange animals in a *natural system* conformable to the fixity of species since their creation as described in Genesis. When he published the revised edition of his work in 1766 he left out his fundamental proposition of the earlier works, that *there were no new species.*

Lockyer, Sir Joseph Norman. Astronomer. B. 1836, at Rugby; d. 1920. He independently originated the spectroscopic method of examining the Chromosphere of the Sun. He led nine eclipse expeditions. Pub. *Chemistry of the Sun, The Sun's Place in Nature, Inorganic Evolution, Our Place among Infinities, Other Worlds than Ours.*

Lodge, Sir Oliver, F.R.S., D.Sc. Physicist. B. 1851. Perhaps more than any other physicist Sir Oliver Lodge has identified himself with the hypothesis of the Ether of Space. Nothing, he says, is more certain than the existence of the Ether. He has refused to discard it despite the claims of neo-Relativists that it is altogether superfluous to their conception of physical phenomena. An American writer, W. F. Hudgings, says: "Sir Oliver Lodge is a leading opponent of the Einstein theory among a certain few British scientists, but his opposition is easily accounted for when it is remembered that Einstein, by ignoring the Ether and denying other unproven hypotheses, has materially upset Sir Oliver's spiritistic playground." Certainly this physicist's views on "life" and "mind" are absolutely unique. Certain "form-waves," he suggests, "constitute the physical mechanism whereby life and mind operate on and direct material particles." "Mind," for Sir Oliver, would appear to be an entity that can act upon, and be acted upon by, matter; it is, further, independent of the brain, for, he says, "Mind itself is not necessarily damaged by damage to the brain." Perhaps it is needless to say that few, if any, physicists share Sir Oliver Lodge's views of "mind," and certainly no psychologists, physiologists, or zoologists. His "scientific" outlook is well shown in the following extract from his address to the British Association on Sept. 29, 1931:—"If we attend to space properly we shall find it is not only on lumps of matter that we find life and mind. Intelligence and mind can be found throughout space: that is what we are coming to, and after a time we shall be led to the further conclusion that life and mind are more important than the material universe. . . ."

Sir Oliver has written widely upon evolutionary subjects. Pub. *Life and Matter*, *Making of Man*, *Man and the Universe*, *Ether and Reality*, *The Ether of Space*, *Electrons*, *Modern Views of Matter*.

LOEB, JACQUES. Zoologist. B. 1859; d. 1924. Late of the Rockefeller Institute. He conducted many wonderful experiments in the artificial fertilization of animals, and his writings show that he held a purely mechanistic conception of life. Pub. *Physiology of the Brain*, *Dynamics of Living Matter*, *Mechanistic Conception of Life*, *The Organism as a Whole*.

LULL, RICHARD SWANN. Professor of Biology at Yale University. B. 1867. His *Evolution* is one of the best and most up-to-date works on the subject.

MACBRIDE, ERNEST WILLIAM, F.R.S., D.Sc. B. Belfast, Dec. 12, 1866. Professor of Zoology, Imperial College of Science, London. Has contributed many publications on evolutionary subjects, especially embryology. Pub. *Invertebrate Embryology*, *Zoology*, *Introduction to the Study of Heredity*.

MCCABE, JOSEPH. B. Nov. 11, 1867. Besides his numerous lectures and addresses, Mr. McCabe has written, in charming style, an immense number of books on Evolution. He translated Haeckel's large two-volume work on the *Evolution of Man*. Among his books the following are of exceptional interest to students of Evolution: *Story of Evolution*, *Evolution of Mind*, *Principles of Evolution*, *End of the World*, *A.B.C. of Evolution*, *Evolution of Civilization*, *Marvels of Modern Physics*.

MAYER, JULIUS ROBERT (1814–78), was born at Heilbronn. In 1842 he consolidated Lavoisier's discovery of the

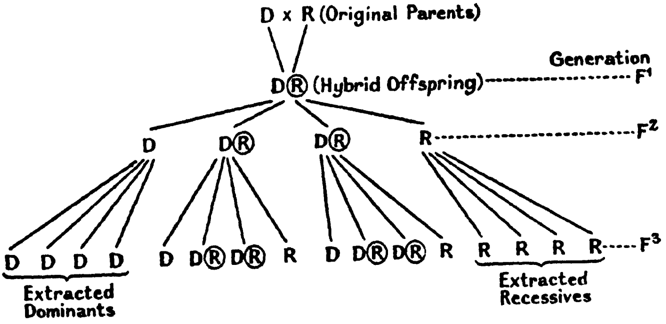
Conservation of Mass by proving the *Conservation of Energy*; in other words, he showed that *energy, like matter, is indestructible.*

MENDEL, GREGOR (1822–84). An Austrian monk. The Mendelian theory of heredity is now accepted by all biologists, though during the lifetime of its discoverer it was unnoticed. Even Darwin was unaware of Mendel's work, which would certainly have profoundly modified some of his views on heredity. The simple Mendelian proportions are obviously at bottom fixed by laws of mathematical probability. The DOMINANTS, that is, obtrusive characters in an organism, and RECESSIVES, or characters which are present only in latent form, suppressed or concealed, appear in ensuing generations with the mathematical precision with which coloured beads drawn in pairs at random from a bag containing equal numbers of them assort themselves. Supposing, for example, that from a bag containing 6,000 black beads (B) and 6,000 white ones (W), thoroughly mixed up, the beads are drawn out blindly, in pairs, and placed on a table one behind the other, it will be found that, on the average, they will come out as follows:

3,000 W behind W.
3,000 B ,, B.
3,000 B ,, W.
3,000 W ,, B.

In other words, the *pairs* will be 3,000 pure white, 3,000 pure black, and 6,000 "hybrids," black and white. Suppose, now, we start with 12,000 seeds taken haphazard from the pods of hybrids resulting from the crossing of green-coloured peas (g) with yellow-coloured ones (y). If these peas be sorted out it will be found that 9,000 are yellow (y) and 3,000 green (g). The proportion is therefore 3 y : 1 g. But this proportion is not really as simple as it looks. These peas if sown, and the resulting flowers strictly fertilized among themselves, behave as follows: the 3,000 green-coloured peas will breed true, that is, they will produce in all subsequent generations nothing but green-coloured peas; they, and their subsequent, pure-bred, green descendants are termed

Extracted Recessives. Of the 9,000 yellow peas, 3,000 will be found to breed true, that is, ever afterwards they will produce nothing but yellow peas; they, and their pure-bred yellow descendants, are called Extracted Dominants. But 6,000 yellow peas are still unaccounted for. It will be found that of these, one-third, that is, 2,000 peas, breed true, producing yellow peas ever after, while the other two-thirds, that is, 4,000 peas, will produce hybrids or peas that do not breed true; and of these hybrids 3,000 will be yellow and 1,000 green, thus showing the same proportion 3 : 1 as at the start. In such an example the yellow peas show obtrusiveness, they are the Dominants; the green peas, on the other hand, show a more retiring disposition, they are the Recessives. This may be made clearer by a diagram where D and R stand respectively for " Dominant " and " Recessive," and DR for " Hybrid," which (in our example) is coloured yellow and, therefore, *apparently dominant*, but which holds the green colour or *recessive character* in a latent and suppressed state. A circle around the R indicates that the character, though present, is concealed.



Mendeléeff, Dmitri (1834–1907). Russian chemist. Professor of Chemistry at St. Petersburg University. Mendeléeff, Newlands, and Meyer, independently of each other, formulated the Periodic Law of the chemical elements, which, by proving the genetic relationship of the elements, has led to the discovery of new elements.

METCHNIKOFF, ELIE. Russian zoologist. B. May 15, 1845; d. July 16, 1916. Professor of Zoology at Odessa. He was one of the pioneers among writers on Evolution. Metchnikoff will ever be famous for his researches into PHAGOCYTOSIS, wherein he demonstrated the amœba-like behaviour of the white blood cells in seizing and devouring intruders into the tissues of the body, such as microbes and foreign bodies generally. The white blood cells constitute a standing army of policemen and soldiers to protect the organism from invasion by "foreigners." Pub. *Nature of Man*, *Prolongation of Life*.

MILLIKAN, ROBERT ANDREWS, Sc.D. American astronomer and astro-physicist. B. March 22, 1868. Vice-President of the American Association for the Advancement of Science. For many years he has devoted himself to research into the mysterious radiations pouring into our atmosphere *day and night* from every angle of the heavens. These rays, he thinks, are of a nature conformable with a genesis of hydrogen and helium in the extremely cold depths of inter-stellar space. The radiations which are manufactured in the depths of incandescent suns consequent upon disintegration of atoms through the high temperatures and pressures there met with (and which, therefore, are the energy equivalents of the protons and electrons that made up the disintegrated atoms) escape at the surface of the suns and ultimately reach the cold depths of inter-galactic space. Here, they are, thinks Millikan, synthesized into hydrogen and helium, which in their turn probably undergo further synthesis into the higher elements such as carbon, oxygen, nitrogen, sulphur, etc., which are known to be present in those vastly distant regions. It is, he believes, during such synthetic processes that these excessively short wave-length cosmic rays are first produced to reach our earth, perhaps many thousands of years later. An analogy may help here. If hydrogen and chlorine gases be mixed in a glass vessel in the dark and a *ray of sunlight* be permitted to enter the mixture, the two gases almost instantaneously combine to form hydrochloric acid. A result of the synthesis of the acid is the radiation of a flash of light. Millikan's theory is much more in keeping with that principle of continuity which appears to underlie all evolutionary processes than is the somewhat pessimistic heat-death theory of the Universe as postulated by Kelvin, Clausius, and Jeans, for it gives us a self-contained Cosmos in which matter that has been broken down and destroyed (as such) in one place is rebuilt in another place. Millikan's theory brings us once more to an infinitely extended, eternally enduring, and ever-fluxing matter-energy Cosmos.

MITCHELL, Sir PETER CHALMERS, F.R.S. B. Dunfermline, Nov. 1864. Secretary of the Zoological Society. Has written several works on Evolution. Pub. *Outlines of Biology*, *Biological Problems*, *Nature of Man* (tr. Metchnikoff), *T. H. Huxley*, *Evolution and the War*, *Materialism and Vitalism*. It is mainly owing to his enterprise and scientific organization that the Zoo extension at Whipsnade has been made, where the public can see animals living in what is almost their natural habitat.

MORGAN, LLOYD, F.R.S. Biologist. B. Feb. 6, 1852, London. Emeritus Professor at the University of Bristol. Has written many works on Evolutionary Biology, in the later ones stressing a principle known as *Emergence*. Pub. *Animal Life and Intelligence*, *Habit and Instinct*, *Animal Behaviour*, *Interpretation of Nature*, *Emergent Evolution*.

OKEN, LORENZO (1779–1851), German naturalist, born at Baden. He was famous for his doctrine of " the *Ur-Schleim* "—viz. " Every organic thing has arisen out of slime, and is nothing but slime in different forms. This primitive slime originated in the sea, from inorganic matter, in the course of planetary evolution." Oken's vertebral theory of the development of the skull through modification of certain vertebræ, fascinating though it be, is not accepted by present-day anatomists.

OSBORN, HENRY FAIRFIELD. American palæontologist. B. Fairfield, Conn., 1857. Research Professor in Zoology. Has written very widely on Evolution. Pub. *From the Greeks to Darwin*, *Age of Mammals*, *Huxley and Education*, *Men of the Old Stone Age*, *Origin and Evolution of Life.*

OWEN, Sir RICHARD (1804–92), was undoubtedly the greatest palæontologist of his age, and, though a bitter opponent of Darwinism (and by no means always over-scrupulous in his manner of attack), his colossal work contributed immensely to the very doctrine he so detested. He was a strong supporter of Oken's theory of the origin of the skull.

PAVLOV, Professor. Russian physiologist. His *Conditioned Reflexes* is an epoch-making work; in it he shows that many every-day routine actions, such as dressing, eating, etc., are largely carried out in the absence of consciousness.

PEARSON, KARL, F.R.S. B. 1857. Galton Professor of Eugenics in the University of London. Has conducted a large amount of research work into the mathematics of evolutionary biology and heredity. Pub. *Ethic of Free Thought*, *Chances of Death and other Studies in Evolution*, *Grammar of Science.*

POULTON, E. B., F.R.S., D.Sc. Zoologist. B. Reading, Jan. 27, 1856. Professor Poulton is the greatest living authority on Mimicry in Animals. Hope Professor of Zoology at the University of Oxford. Romanes Lecturer. Pub. *Colours of Animals*, *Charles Darwin and the Theory of Natural Selection*, *Essays on Evolution*, *Charles Darwin and the Origin of Species.*

PYCRAFT, W. P. Zoologist. B. 1868. Assistant Keeper, Osteology, British Museum. Pub. *Story of Bird Life*, *Story of Reptile Life*, *Story of Fish Life*, *Infancy of Animals*, *Courtship of Animals.* The last two works are full of interesting and little-known facts of evolutionary significance.

QUINTON, R. Physiologist. Independently with Professor Macallum he conceived the idea that the blood of living animals furnishes a valuable clue to the temperature and composition of the early pre-Cambrian seas. Our " naked " ancestors dwelt immersed in a saline fluid; each of their cells was, consequently, saturated with salt water. When, with the advent of a protective and enclosing membrane or skin, the cells got shut off from direct contact with the sea-water they retained some of it as their " vital fluid," which, circulating, became the blood and lymph streams. These in chemical composition were practically identical with that of the pre-Cambrian sea-water in which the unclosed cells of their ancestors had been immersed. When these aquatic skin-enclosed animals left the seas and became terrestrial they carried with them, so to speak, this modified saline fluid sealed up inside their bodies. Though necessarily remanufactured at each new generation, heredity has conserved it in more or less the same chemical proportions ever since. Hence it is that our body-fluids generally—the blood in the vessels, the lymph in the lymph-spaces, the tears cleansing the surface of the eye, the lubricating " oil " of our joints, the fluid bathing each cell, the amniotic liquid in which the fœtus is immersed—are, in essence, a dilute sea-water, or what the biochemist terms a " normal saline solution." The pre-Cambrian seas are known to have been less saline than modern seas, and so our body fluids contain a smaller percentage of total salts than do the seas of to-day, but are more or less identical in salinity with those of pre-Cambrian times. Without the regular and constant presence of this miniature salt sea not one of our cells could live a moment. An amœba or a human blood corpuscle placed in pure water dies immediately.

REID, Sir GEORGE ARCHDALL, F.R.S.E. B. Roorky, India, April 7, 1860; d. 1929. Sir Archdall was an ardent Evolutionist and a keen fighter against Lamarckians in biology and neo-Relativists in physics. Pub. *Present Evolution of Man*, *Alcoholism: a Study in Heredity*, *Principles of Heredity*, *Laws of Heredity*. A large book on Eugenics and Evolution was being completed when his untimely death occurred. Sir Archdall believed that mankind, through survival of *germ-cells* that are tolerant towards certain poisons intimately associated with civilization (such as alcohol, nicotine, and the toxines liberated by the *Spirochæte pallida*, the protozoon of syphilis, and other " microbes " more or less specialized for a habitat in man's tissues) and the elimination of germ-cells that are susceptible to them, is gradually acquiring an immunity against such poisons. This is not the transmission of an *acquired character*, for the " selection " of the fitter cells and " rejection " of the less fit ones take place entirely among the germ-cells, irrespective of the body-cells.

ROMANES, GEORGE JOHN. B. Kingston, Canada, 1848; d. May 23, 1894. His works, *Animal Intelligence* and *Darwin and After Darwin*, rendered valuable service.

RUTHERFORD, Sir ERNEST, O.M., F.R.S. B. Nelson, New Zealand, Aug. 30, 1871. Cavendish Professor of Experimental Physics, Cambridge University. Professor of Natural Philosophy, Royal Institution. One of the pioneers in Radio-Activity of the Elements. Pub. mostly in the Transactions of the Royal Society, *Radio-Active Transformations, Radio-Active Substances and their Radiations.*

SALEEBY, CALEB, M.D., F.R.S.E. Eugenist. B. Worthing, 1878. In his several lectures, papers, and books he has done splendid work in popularizing the doctrine of Evolution. Pub. *Cycle of Life*, *Sunlight and Health*, *Parenthood and Race Culture.* His *Evolution the Master Key* is one of the best summaries extant of Herbert Spencer's philosophy and is, moreover, written in very attractive style.

SCHLEIDEN, MATTHIAS (1804–81). B. Hamburg. Professor of Botany at Jena. He discovered the method of cell-growth in plants.

SCHWANN, THEODOR (1810–82). Professor of Anatomy at Louvain. He rejected the traditional *vitalism* and inclined towards the modern physico-chemical theory of life. It was Schwann who discovered the true nature of fermentation. With Schleiden he made important researches into cell-structure, and both observers noted the many common features of animal and plant-cells—thus paving the way for the future work of Pasteur, Virchow, and Lister.

SHARPEY-SCHAFER, Sir EDWARD, F.R.S. Physiologist. B. London, June 2, 1850. One of the pioneers in research on the endocrine organs and the part their secretions play in the manifestation of the emotions. As President of the British Association in 1912 he advanced the new view that the origin of life took place, not in the primordial oceans as almost all biologists believe, but in the upland fresh waters. His hypothesis, however, runs counter to too many known facts. It is in conflict, for instance, with the relatively high degree of salinity of the fluids in which the cells of our body and those of animals generally are immersed. (*See* Quinton.) Pub. *Quain's Anatomy*, *Advanced Physiology*, *The Endocrine Organs.*

SHERRINGTON, Sir CHARLES SCOTT, O.M., F.R.S. Waynfleete Professor of Physiology, Oxford. Past President of Royal Society. Pub. *Mammalian Physiology*, *Integrative Action of the Nervous System.* The latter can best be described as a classic in the physiology of the nervous system.

SHIPLEY, Sir ARTHUR EVERETT, F.R.S. Entomologist. B. March 10, 1861; d. 1927. Formerly Vice-Chancellor of Cambridge University. Has done a great deal of research in connection with insect pests and parasites. Pub. *Life*, *Zoology of the Invertebrates*, *Pearls and Parasites*, *Studies in Insect Life.* He was one of the translators of Weismann's *Heredity.*

SMITH, GRAFTON ELLIOT, F.R.S. B. Aug. 15, 1871. Past Vice-President, Royal Society. Professor of Anatomy, London University. Comparative anatomist and anthropologist and a foremost authority on the comparative anatomy of the brain. Has written widely on evolutionary subjects. Elliot Smith calls the primitive part of the human brain, which is concerned chiefly with the sense of smell, the ARCHIPALLIUM. In the evolution of the pre-human brain a time came when it became advantageous to blend and co-ordinate the incoming impulses to the ARCHIPALLIUM from the nose with those from other sense-organs, eye, ear, skin, etc. This great co-ordinating network of nerve-cells (one of the latest products of evolution) which makes up the principal part of the human brain he calls the NEOPALLIUM. He has recently been making a special study of the skull of Peking man, HOMO SINANTHROPUS, discovered by W. C. Pei, a Chinese geologist, at Chou Kou Tien near Peking on Dec. 2, 1929. SINANTHROPUS, Elliot Smith states, is a generalized form intermediate between the ape-man PITHECANTHROPUS and Piltdown man, EOANTHROPUS. This ancestral China-man probably roamed the Western Hills flanking Peking a million years ago, in the Pliocene period. Pub. *On Mummies*, *Evolution of Man*, *Essays on Evolution*, *History of Civilization*, *Peking Man*, *Human History*, *The Search for Man's Ancestors.*

Smith, William (1769–1839). English geologist. His geological survey of England led him to conceive the idea of a *definite and orderly succession of life*, as against the theory of Cuvier and his school, that the flora and fauna of each epoch were periodically destroyed by convulsions of Nature, after each of which the earth was reclothed with vegetation and repeopled with animals by a fresh creative act! It was Smith who placed in the hands of Sir Charles Lyell (1797–1875) the particular weapon that enabled him, when in 1830–33 he published his *Principles of Geology*, to give the death-blow to Cuvier's Catastrophic theory of the history of the earth.

Smuts, Lieut.-Gen. the Rt. Hon. **Jan Christian**, F.R.S. B. 1870. Author of *Holism and Evolution.* As President of the British Association in 1931 he attempted in his theory of Holism (*Holos*, whole or entire) to delineate the Cosmos as the evolutionary product of a single fundamental entity, *space-time.* Despite the fact that Planck, the inventor of the quantum physics, distinctly avers that he sees no evidence necessitating the abandonment of determinism, General Smuts stated that the quantum theory "gives definite indications of indeterminism in nature." His Holism, with *space-time* as the cosmic physical basis, would seem to be a metaphysical variant of neo-materialistic Monism which, while likewise depicting the Cosmos as an organic whole, postulates *matter-energy* as its physical basis.

Soddy, Frederick, F.R.S. B. Sept. 2, 1877. Professor of Physical Chemistry, Oxford. One of our foremost authorities on radio-activity. Pub. *Chemistry of the Radio-Elements*, *Matter and Energy*, *Science and Life*, *Inversion of Science.*

Sollas, William J., F.R.S. Geologist and archæologist. B. May 30, 1849. Has made special researches into the structure of the earth and on prehistoric man. Pub. *Age of the Earth*, *Ancient Hunters.*

SPENCER, HERBERT. B. at Derby on April 27, 1820; d. at Brighton on Dec. 8, 1903. The great synthetic philosopher. In 1852 he had written a paper giving a clear presentation of the general doctrine of Evolution, and in the *Principles of Biology* (1863–66) he gave the theory of Organic Evolution a philosophic expression. He used the phrase "survival of the fittest," and it is marvellous how near he was to discovering Natural Selection. He gave his life to establishing the great principle of Evolution, and to applying it to physical, biological, psychological, and social facts. His works are a monument of genius and industry.

SWAMMERDAM, JAN (1637–80). Dutch naturalist. Discovered the valves of the lymphatic vessels, the sporangia and spores of lowly plants, and was the first to see and describe "little rounded lumps" in frog-embryos—thus anticipating the discovery of the "cell." Like so many of the natural theologians of his day he always closed the "chapters" of his great book, *Biblia Naturæ*, with expressions of pious admiration, being convinced that the universe was made solely for the use of man. While lauding the adaptations which secure the well-being of animals, he maintained a discreet silence about the terrible sufferings to which they are also subjected.

TENNYSON, ALFRED, Lord (1809–92). Poet laureate. If Lucretius was the first poet of Evolution, Tennyson certainly deserves to be called the last. He says:

"Many an Æon moulded earth before her highest, man, was born,
Many an Æon too may pass when earth is manless and forlorn."

And again:

"Evolution ever climbing after some ideal good,
And Reversion ever dragging Evolution in the mud."

His insight into the method of Selection in Evolution is well shown in "So careful of the type she seems, so careless of the single life."[1]

THOMSON, Sir JOHN ARTHUR, M.A., LL.D. B. July 8, 1861. Emeritus Professor of Natural History,

---

[1] As these lines were written before the publication of *The Origin of Species*, it will be seen that Tennyson, to a certain extent, anticipated Darwin's central idea.

Aberdeen. Has written widely on Evolution in a very captivating style. Perhaps the two most famous of his works (written jointly with Patrick Geddes) are the earliest (1889), *Evolution of Sex*, and latest (1931), *Life; Outlines of General Biology* (2 vols.). His other writings include *Outlines of Zoology*, *Study of Animal Life*, *Herbert Spencer*, *Heredity*, *Darwinism and Human Life*, *Biology of the Seasons*, *Evolution*, *Wonders of Life*, *What is Man?*

THOMSON, Sir JOSEPH JOHN, F.R.S., O.M. Physicist. B. Dec. 18, 1856, Manchester. Past President of the Royal Society. Past Cavendish Professor of Experimental Physics. A pioneer in the modern electrical theory of matter, for he was the first scientist to "split the atom." Pub. *On the Motion of Vortex Rings*, *Electricity and Magnetism*, *Structure of Light*.

TYNDALL, JOHN, F.R.S. Physicist. B. Aug. 2, 1820; d. 1893. He was a great friend of Huxley and an ardent champion of Darwin. In his Presidential Address at the British Association in 1874 at Belfast he said: "We claim and we shall wrest from theology the entire domain of cosmological theory." Tyndall made many original researches into the movements of glaciers. His *Heat as a Mode of Motion* and his *Fragments of Science* still make, despite the revolution caused by the "splitting of the atom," delightful and instructive reading.

VRIES, HUGO DE. Dutch botanist. B. Feb. 16, 1848. Emeritus Professor of Botany, University of Amsterdam. He initiated the theory of MUTATION as one of the methods of Evolution (a theory now generally accepted by biologists), conceiving the idea from observing "sports" in the Evening Primrose (*Œnothera Lamarckiana*). He has proved that in this and other plants Evolution undoubtedly progresses by sensible "jumps" rather than by gradual and imperceptible steps. Pub. *Mutation Theory*, *Species and Varieties*, *Plant Breeding*.

WALLACE, ALFRED RUSSEL. B. at Usk in Monmouthshire, Jan. 8, 1823; d. 1913. He travelled with Bates along the Amazon and made collections of natural-history specimens; sailed in 1854 for the Malay Archipelago for the same purpose. When lying ill with fever at Ternate, in February 1858, something led him to think of the "positive checks" described by Malthus in his essay on *Population.* He says: "There suddenly flashed on me the *idea* of the survival of the fittest, and in the two hours that elapsed before my ague fit was over I had thought out the whole of the theory, and in the two succeeding evenings wrote it out in full, and sent it by the next post to Mr. Darwin."

It is remarkable that both Darwin and Wallace should have independently discovered the same theory, and have expressed it in almost the same words, and that they should have *suddenly* hit upon it in thinking over the same book. Darwin wrote an abstract of his *Origin* which was read with Wallace's paper at a meeting of the Linnean Society on July 1, 1858.

WATSON, DAVID MEREDITH, F.R.S. B. June 18, 1886. Jodrell Professor of Zoology and Comparative Anatomy, University of London. Has written many papers and articles on Vertebrate Palæontology and kindred evolutionary subjects.

WEISMANN, AUGUST (1834–1914). German biologist. Famous as being the first biologist to deal with heredity from a purely physico-chemical standpoint. His great thesis was the *Continuity of the Germ Plasm.* Children resemble parents because they are made of the same material; the stream of protoplasm, represented by the chain of dividing germ-cells, passes on from generation to generation and, like the ever-dividing protozoa, the germ-cells that form the links of the chain, or rather of a series of diverging chains, are, within the limits of the many million years since the dawn of life, immortal!

WELLS, HERBERT GEORGE, B.SC. B. September 21, 1866. First-class honours in zoology, Royal College of Science. Author of *Outline of History,* in which the story is told of our earth and its inhabitants since Palæozoic days. Joint author with Julian Huxley and G. P. Wells of *Science of Life,* a magnificently illustrated work that deals exhaustively with the complex body-machine of man and lower animals, and explains, so far as modern science permits, how it came to be, how it functions, and how it multiplies.

WHEELER, WILLIAM MORTON. B. 1865. Professor of Entomology, Harvard University. Biologist. Professor Wheeler has associated himself especially with the study of Insects and he has written many charming descriptions of the habits of ants, bees, beetles, etc.

WIEDERSHEIM, ROBERT. B. April 21, 1848. Late Professor of Comparative Anatomy at Freiburg. He wrote *Elements of the Compaıative Anatomy of Vertebrates* and *The Structure of Man*, both of which teem with interesting facts concerning man's evolution.

WOODWARD, Sir ARTHUR SMITH, F.R.S. Zoologist. B. May, 23, 1864. Past Keeper, Geological Department, British Museum. He has made a special study of the extinct Vertebrates of South America and has catalogued, in four volumes, the Fishes in the British Museum. Co-operated with Charles Dawson in the discovery of the Piltdown skull (*Homo Eoanthropus*). Pub. *Fossil Fishes, Outlines of Vertebrate Palæontology.*

Such are a few of the great men whose toil has helped in interpreting the universe to man. When we have quite left our barbarism behind, instead of recording battles we shall mark our calendars by the birthdays of these pioneers " who battled for the True."

DARWIN IS DEAD ; DARWINISM LIVES.

BOOKS RECOMMENDED.

Popular. For General Readers.

A B C of Evolution. Joseph McCabe. (Watts.)
Age of the Earth. Arthur Holmes. (Benn.)
Animals of the Past. F. A. Lucas. (American Museum of Natural History, New York.)
Anthropology. R. R. Marett. (Thornton Butterworth.)
Atom, The. E. N. da C. Andrade. (Benn.)
Atoms and Electrons. J. N. Sullivan. (Hodder and Stoughton.)
Beginnings of Man. E. O. James. (Hodder and Stoughton.)
Call of the Stars. John R. Kippax. (Putnam.)
Childhood of the World. Edward Clodd. (Kegan Paul.)
Concerning Man's Origin. Sir Arthur Keith, F.R.S. (Watts.)
Courtship of Animals. W. P. Pycraft. (Hutchinson.)
Creation by Evolution. Collective. Ed. by Frances Mason. (Macmillan.)
Darwinism. A. R. Wallace. (Macmillan.)
Darwinism and Human Life. Sir J. A. Thomson. (Hutchinson.)
Darwinism and the Problems of Life. Conrad Guenther. Tr. by Joseph McCabe. (A. Owen.)
Darwinism and What It Implies. Sir Arthur Keith, F.R.S. (Watts.)
Descent of Man. Charles Darwin. (Murray.)
Descent of Man. W. Boelsche. (Simpkin Marshall.)
Earth, The. Edward Greenly. (Watts.)
Easy Outline of Evolution. Dennis Hird. (Watts.)
Eos, the Wider Cosmogony. Sir James Jeans, F.R.S. (Kegan Paul.)
Essence of Astronomy. E. P. Price. (Putnam.)
Evolution. E. W. McBride, F.R.S. (Benn.)
Evolution. J. A. S. Watson. (Nelson.)
Evolution. J. Graham Kerr. (Macmillan.)
Evolution. Sir J. A. Thomson and Sir Patrick Geddes. (Thornton Butterworth.)
Evolution. Vernon L. Kellogg. (Appleton.)
Evolution Explained. J. T. Parsons. (Bale.)
Evolution of Animal Intelligence. S. J. Holmes. (Holt.)
Evolution of Mind. Joseph McCabe. (Watts.)
Evolution of Plants. D. H. Scott, F.R.S. (Thornton Butterworth.)
Evolution of Sex in Plants. J. M. Coulter. (University of Chicago.)
Evolution of the Horse. F. B. Loomis. (Marshall Jones.)
Evolution of Vertebrates. William Patten. (Blakiston.)
Extinct Plants and Problems of Evolution. D. H. Scott, F.R.S. (A. & C. Black.)

First Book of Organic Evolution. D. K. Shute. (Open Court.)
Footprints of Early Man. D. A. Mackenzie. (Blackie.)
From Monkey to Man. L. H. Dudley Buxton. (Routledge.)
Geology. Sir P. Geddes and Sir A. Thomson. (Thornton Butterworth.)
Human Body, The. Sir Arthur Keith, F.R.S. (Thornton Butterworth.)
Human Origins. G. G. McCurdy. (Appleton.)
Infancy of Animals. W. P. Pycraft. (Hutchinson.)
Interpretation of Nature. Lloyd Morgan, F.R.S. (Macmillan.)
Links with the Past in the Plant World. A. C. Seward. (Cambridge.)
Making of the Earth. J. W. Gregory. (Thornton Butterworth.)
Man in the Making. R. R. Marett. (Benn.)
Matter and Energy. F. Soddy, F.R.S. (Thornton Butterworth.)
Mechanism of Nature. E. N. da C. Andrade. (Bell.)
Mentality of Apes. W. Kohler. (Harcourt and Brace.)
Method of Evolution. H. W. Conn. (Putnam.)
Mind in Evolution. L. T. Hobhouse. (Macmillan.)
Mutation Theory. Hugo de Vries. (Open Court.)
Mutual Aid as a Factor in Evolution. Prince Kropotkin. (Heinemann.)
Nature of Man. Elie Metchnikoff. (Heinemann.)
Nature of the World and of Men. H. H. Newman. (University of Chicago.)
Origin and Evolution of Primitive Man. Albert Churchward. (George Allen.)
Origin and Nature of Life. Benjamin Moore, F.R.S. (Thornton Butterworth.)
Origin of the Family. Frederick Engels. (Kerr, Chicago.)
Origin of the World. R. McMillan. (Watts.)
Our World and Us. A. G. Whyte. (Watts.)
Pedigree of Man. Ernst Haeckel. (Bonner.)
Races of Mankind. H. J. Fleure. (Benn.)
Savage Survivals. J. Howard Moore. (Watts.)
Social and Organic Evolution. A. M. Lewis. (Kerr, Chicago.)
Stars in their Courses. Sir James Jeans, F.R.S. (Cambridge U.P.)
Story of Creation. Edward Clodd. (Longmans.)
Structure and Properties of Matter. W. A. Caspari, D.Sc. (Benn.)
Studies in Animal Behaviour. S. J. Holmes. (Badger, Boston.)
Studies in the Evolution of Animals. E. Bonavia. (Constable.)
Within the Atom. John Mills. (Routledge.)
Wonder World, The. A. G. Whyte. (Watts.)

More advanced Books, but not over-technical.

Ancient Hunters. W. J. Sollas, F.R.S. (Macmillan.)
Animal Biology. J. B. S. Haldane and J. S. Huxley. (Oxford U.P.)
Antiquity of Man. 2 vols. Sir Arthur Keith, F.R.S. (Williams and Norgate.)
Antiquity of Man in East Anglia. J. Reid Moir. (Cambridge U.P.)
Apes and Men. Peake and Fleure. (Oxford U.P.)
Arboreal Man. F. Wood Jones. (Arnold.)
Astronomy and Cosmogony. Sir James Jeans, F.R.S. (Cambridge U.P.)
Biology of Death. Raymond Pearl. (Lippincott; Philadelphia.)
Cambridge Natural History—Zoology. 12 vols. Collective. (Macmillan.)
Darwinism To-day. Vernon L. Kellogg. (George Bell.)
Depths of the Universe. George E. Hale. (Scribner.)
Earth, its Genesis and Evolution. A. T. Swaine. (Charles Griffin.)
Earth's Beginnings, The. Sir Robert S. Ball, F.R.S. (Cassell.)
Emergent Evolution. W. Morton Wheeler. (Kegan Paul.)
Evolution. Geddes and Thomson. (Thornton Butterworth.)
Evolution and Progress of Mankind. Herman Klaatsch. Tr. Joseph McCabe. (Fisher Unwin.)
Evolution in the Light of Modern Knowledge. (Collective.) (Blackie.)
Evolution of Man. G. A. Baitsell. (Yale University.)
Evolution of Man. Lull and Ferris. (Oxford U.P.)
Evolution of Man. Elliot Smith, F.R.S. (Oxford U.P.)
Evolution of Sex. Geddes and Thomson. (Walter Scott.)
Evolution of the Earth and Its Inhabitants. R. S. Lull and others. (Yale U.P.)
Exploring the Universe. Henshaw Ward. (Bobbs-Merrill, Indianapolis.)
Expression of the Emotions. Charles Darwin. (Murray.)
Footnotes to Evolution. David S. Jordan. (Appleton, N.Y.)
Fossil Men. M. Boule. (Ritchie.)
Fossil Plants. 4 vols. A. C. Seward, F.R.S. (Cambridge U.P.)
Geology. 2 vols. T. C. Chamberlin and R. D. Salisbury. (Henry Holt, N.Y.)
Gist of Evolution. H. H. Newman. (Macmillan.)

History of the Human Body. H. H. Wilder. (H. Holt.)
Human Embryology. Sir Arthur Keith, F.R.S. (Arnold.)
Ice Ages. A. P. Coleman. (Macmillan.)
Intermediate Text-Book of Botany. E. Evans. (Longmans.)
Introduction to Anthropology. E. O. James. (Macmillan.)
Man a Machine. Joseph Needham. (Kegan Paul.)
Man an Adaptive Mechanism. George Crile. (Macmillan.)
Man and his Universe. J. Langdon-Davies. (Harper.)
Man's Mental Evolution. Harry Campbell. (Baillière, Tindall, and Cox.)
Men of the Old Stone Age. H. F. Osborn. (Bell.)
Mysterious Universe, The. Sir James Jeans, F.R.S. (Cambridge U.P.)
Nature and Origin of Life. Felix le Dantec. (Hodder and Stoughton.)
New Discoveries Relating to the Antiquity of Man. Sir Arthur Keith, F.R.S. (Williams and Norgate.)
Organic Evolution. A. S. Lull. (Macmillan.)
Organic Inheritance in Man. F. Crew. (Oliver and Boyd.)
Origin and Evolution of Life. H. F. Osborn. (J. Bell.)
Origin of Species. Charles Darwin. (Watts.)
Outlines of Evolutionary Biology. Arthur Dendy, F.R.S. (Constable.)
Outlines of Zoology. Sir J. Arthur Thomson. (Oxford U.P.)
Pedigree of the Human Race. H. H. Wilder. (Harrap.)
Practical Zoology. A. T. Masterman, F.R.S.E. (E. and S. Livingstone.)
Pre-History. M. C. Burkitt. (Cambridge U.P.)
Pre-Palæolithic Man. J. Reid Moir. (Simpkin.)
Primary Factors of Organic Evolution. E. D. Cope. (Open Court.)
Primitive Animals. Geoffrey Smith. (Cambridge U.P.)
Problems of Life and Reproduction. Marcus Hartog. (Murray.)
Quaternary Ice Age. W. B. Wright. (Macmillan.)
Stone Age, The. E. O. James. (S.P.C.K.)
Structure of Man. R. Wiedersheim. (Macmillan.)
Studies in Fossil Botany. D. H. Scott. (A. and C. Black.)
Studies in Insect Life. A. E. Shipley, F.R.S. (Fisher Unwin.)
Super-Organic Evolution. Enrique Lluria. (Williams and Norgate.)
Text-book of Geology. Lake and Rastall. (Arnold.)
Theory of Organic Evolution. W. B. Scott. (Macmillan Co.)
Treatise on Comparative Embryology. 3 vols. F. M. Balfour. (Macmillan.)
Universe and the Atom, The. M. Erwin. (Constable.)
Universe Around Us, The. Sir James Jeans, F.R.S. (Cambridge U.P.)

Weismann on Heredity. 2 vols. E. B. Poulton, F.R.S., Schonland, and Shipley. (Oxford U.P.)
What Evolution is. G. H. Parker. (Oxford U.P.)
Zoological Philosophy. Lamarck. Tr. Hugh Elliot. (Macmillan.)

Books giving a Bird's-eye View of Evolution.

Almost Human. R. M. Yerkes. (Appleton.)
Animal Intelligence. G. J. Romanes, F.R.S. (Appleton.)
Animal Intelligence. E. L. Thorndike. (Macmillan.)
Child, The : a Study in the Evolution of Man. A. F. Chamberlain. (Walter Scott.)
Comparative Physiology. L. T. Hogben. (Sidgwick and Jackson.)
Critique of the Theory of Evolution. T. H. Morgan. (Princeton University.)
Darwin and After Darwin. 3 vols. G. J. Romanes, F.R.S. (Longmans.)
Discourses, Biological and Geological. T. H. Huxley. (Macmillan.)
Essays of a Biologist. Julian Huxley. (Chatto.)
Essays on Evolution. E. B. Poulton, F.R.S. (Oxford U.P.)
Evolution and Adaptation. T. H. Morgan. (Macmillan.)
Evolution ; Nebula to Man. Joseph McCabe. (Milner.)
Evolution of Matter. Gustave le Bon. (Walter Scott.)
Evolution of the Idea of God. Grant Allen. (Watts.)
Evolution the Master Key. C. W. Saleeby, F.R.S.E. (Harper.)
First Principles. Herbert Spencer. (Williams and Norgate.)
Fragments of Science. John Tyndall, F.R.S. (Longmans.)
Human History. Elliot Smith, F.R.S. (Cape.)
Intelligence of Chimpanzees. R. M. Yerkes. (Williams and Wilkins.)
Kingdom of Man. Sir E. Ray Lankester, F.R.S. (Constable.)
Laws of Heredity. Sir Archdall Reid, F.R.S.E. (Methuen.)
Life and Death. A. Dastre. (Walter Scott.)
Life and Letters of Charles Darwin. Sir Francis Darwin. (Murray.)
Life of the Universe. 2 vols. Svante Arrhenius. (Harper.)
Life ; Outlines of General Biology. 2 vols. Sir Arthur Thomson and Sir Patrick Geddes. (Williams and Norgate.)
Man's Place in Nature. T. H. Huxley. (Macmillan.)
Mechanism, Life, and Personality. J. S. Haldane. (Murray.)
Minds of Animals. Sir J. Arthur Thomson. (Newnes.)
More Letters of Charles Darwin. Francis Darwin. (Murray.)
Nature of Living Matter. Lancelot Hogben. (Kegan Paul.)

Origin of Land Flora. F. O. Bower. (Macmillan.)
Outline of History. H. G. Wells. (Cassell.)
Pioneers of Evolution. Edward Clodd. (Cassell.)
Plants of the Past. F. H. Knowlton. (Oxford U.P.)
Principles of Biology. Herbert Spencer. Revised edition, 1908. (Williams and Norgate.)
Principles of Evolution. Joseph McCabe. (Collins.)
Religion of a Darwinist. Sir Arthur Keith, F.R.S. (Watts.)
Riddle of the Universe. Ernst Haeckel. (Watts.)
Science in Arcady. Grant Allen. (Gibbings.)
Theory of Evolution. W. B. Scott. (Macmillan.)
Tree Ancestors. E. W. Berry. (Williams and Wilkins.)
Worlds in the Making. Svante Arrhenius. (Harper.)

Books on Evolution where Illustrations are a Feature.

Evolution in the Past. Henry Knipe. (Herbert and Daniel.)
Evolution of Man. 2 vols. Ernst Haeckel. Tr. Joseph McCabe. (Watts.)
Extinct Animals. Sir E. Ray Lankester, F.R.S. (Constable.)
Extinct Monsters. H. N. Hutchinson. (Chapman and Hall.)
From Nebula to Man. Henry Knipe. (J. M. Dent.)
History of Creation. 2 vols. Ernst Haeckel. Tr. E. Ray Lankester, F.R.S. (Kegan Paul.)
Lectures on Biology. Curt Thesing. (Bale.)
Our Prehistoric Ancestors. D. Davison. (Methuen.)
Science of Life, The. H. G. Wells, G. P. Wells, and Julian Huxley. (Cassell.)
Splendour of the Heavens. Collective. (Hutchinson.)
Water-Reptiles of Past and Present. S. W. Williston. (University of Chicago.)
Wonders of Animal Life. Ed. by Sir J. A. Hammerton. (Amalgamated Press.)
Wonders of the Past. Ed. by Sir J. A. Hammerton. (Amalgamated Press.)

INDEX

(An Asterisk indicates an Illustration)

Abiogenesis, 229, 260
Acceleration, 267
Acheulean culture, 259*
Acorn-worm. *See* Balanoglossus.
Acrania, 243
Actinodon, 246*, 247*
Actinopterygii, 96
Action at a distance, 267
Adami, J. G., 263
Adams, J. C., 28
Adapis, 80*
Adaptation to environment, 266
Aerolite. *See* Meteorite.
Alimentary canal, early stages of, 237*
Allen, Grant, 263
Allosaurus, 74
Almagest, 261
Alouatta, 252*
Alpha Centauri, 31
Amœba, 87, 200*, 201, 229, 233, 234*
Amœboid cell, 197*
Amphibia, first appearance, 165
Amphibian, hand of, 179*
Amphibians, age of, 64
  early, 246*, 247*
  number of species, 101
  origin of, 101
  roof-headed, 71*
Amphimixis, 202, 204
Amphioxus, 91, 92*, 231, 242*, 243
  gastrulation of, 213*
  larva of, 240*
  palingenesis of, 159*
Amphisbæna, 100, 101*
Amphitherium, 119
Anabolism, 204
Analogous organs, 112
Anaxagoras, 260
Anaximander, 260
Ancestral stripes, 156*
Anchitherium, 12
  evolution of, 10*
Animal cells, 205*
Annihilation, meaning of, 275
Ant-eater, 157*, 249*
  prominence, 42*
Anthropoidea, 125, 128
Anthropopithecus, 255*
Anthropozoic. *See* Quaternary.
Antlers, evolution of, 160*
Ape, brain of, 187*
Aphanostomum, 236*
Appendicitis, 223
Appendicularia, 231, 238, 241*
Apteryx, 112*, 113
Archæan rocks, 67
Archægosaurus, 71*, 247*
Archæopteryx, 111*, 112, 163*
Archipallium, 285
Aristotle, 259, 260
Armadillo, 157*, 158, 266
Arrhenius, 31, 263
Arsinoitherium, 79*
Artificial Selection, 146, 148*, 151
Artiodactyles, 169, 170
Ascidian, 90, 92*, 241, 243
  larva of, 240*
  palingenesis of, 159*
Ass, evolution of, 10*, 14
Asteroids, position and size of, 37*
Asteroids, orbit of, 20*
Atavism, 157, 158, 260
Atom, the, 288
Atomistic philosophy, 260
Aurignacian culture, 259*
Australopithecus, relationship to Man, 258*
Aye-Aye, 126*, 127
Azilian culture, 259*

Ba, 23
Bacilli, 198*
Backbone, 93*, 243
  origin of, 230, 231
Bacteria, 198*, 199
Baer, von, 263
Balanoglossus, 89, 90*, 231, 238, 239
Ball, R., 44
Bartlett, Mr., 127
Basalt, 61*
Bat, 110*, 121*
Bather, F., 263
Beadnell, H. J. L., 79, 81
Beddard, F., 123, 133, 134
Bernard, Claude, 263
Bicycle, evolution of, 2, 3*, 4*, 5

Bimana, 175
Biogenesis, 158, 159
Biogeny. *See* Biogenesis.
Bionomics, 153
Bird, gill-arches in, 216*
  limb of, 110*
Birds, number of species, 101
Black ape, 253*
Black lemur, 125*
Bland-Sutton, 263
Blastæad, 234
Blastosphere, 214
Blenny, 97, 98*
Blood, as index of evolution, 231–233, 282, 283
  cells, 197*
  significance of salt in, 283
  temperature of, 117
Body, nature of, 230
Bon, Gustave le, 264
Books on evolution, 291–296
Bose, Chandra, 264
Bradley, J. H., 76
Brain, evolution of, 243, 285
  of Chimpanzee, 192*
  of Duck-mole, 189*
  of Embryo Chick, 191*, 192*
  of Kangaroo, 189*
  of Man, 184, 185*, 186*, 188* 192*
  of Man and Ape, 189*, 193
  of Rabbit, 106*
Brains, comparative sizes, 190*, 191*
  of mammals, 187*, 188*
Branchiosaurus, 72*
Brontosaurus, 74*
Browne, Buckston, 266
Buddha, 259
Buffon, 264
Burbank, Luther, 264
Burnett salmon, 97*

Ca, 23
Cæcilia, 100, 101*
Cainozoic, 78
Calamoichthys, 96
Calcaneus, 175
Calcolynthus, ovum of, 234*
Calf embryo, 219*
Cambrian, 68, 68*
Canidæ, 151
Cannon bone, 14
Capacity factor of energy, 274
Carboniferous, 64 69
Carnivora, 124
Carnot, 275
Catarrhines, 128, 129*, 132, 253* 254*, 255*
Catastrophic theory, 86, 286
Cebidæ, 130*, 131
Celebesian Ape, 253*
Cell cycle, 206*
Cell, discovery of, 287
  fission, 203*, 213*, 230
  fusion, 203*, 230
Cells, 197*, 205*
  significance of salts in, 283
Cenogenesis, *See* Cœnogenesis.
Centre of gravity, 262
Cepheid variables, 50
Ceratodus, 96, 177, 246*
  limb of, 178*
Cercopithecidæ, 83, 132
Cerebellum, 184
Ceres, 23
Chætonotus, 238*
Chamberlin, 37
Chellean culture, 259*
Chemotaxis, 230
Cheops, 259
Chick embryo, 218*
Chicken, brain of, 191*, 192*
Chimæra, 96*
Chimæridæ, 96
Chimpanzee, 136,* 137, 139*
  brain of, 188*, 192*
  hair of, 182*
Chimpanzees' tea-party, 255*
Cholera bacillus, 198*
Chordates, 165, 240
Chromatin bodies, 200,* 201, 207
Chromosomes, 207–212
Chroococcus, 233*
Chrysanthemum, 154*, 155*, 156
Circulation, discovery of, 271
Cladothrix, 198*
Classification, 155
Clausius, 272, 281
Cleavage, cell, 203*, 213*, 230
Climbing perch, 99*
Clock, a cosmic, 166*
Clodd, E., 264

Cœlomata, 89
Cœnogenesis, 159, 271
Comets, 48*, 49
Conditioned reflexes, 282
Condylarthra, 65
Coney. *See* Hyrax.
Conjugation, 202, 229
Conocyema, 88*
Conservation of Energy, 46, 271, 274, 275, 277
Conservation of Mass, 274, 275
  of Matter, 46
Continuity of germ-plasm, 289
  principle of, 57, 281
Convergence, 112
Cope, E., 265
Copelata, 241*
Copernicus, 259, 261, 262
Corpus callosum, 116, 118, 184, 186*
Coryphodon, 78
Cosmic clock, 166*
  day, 165, 166
  rays, 280
Cosmos, conceptions of, 268, 269, 272, 286
Craniata, 243
Creation, significance of, 275
Creodonta, 65, 119
Cretaceous, 65, 74
Crile, G., 265
Cromagnon Man, relationship to modern Man, 258*
Crommelin, A. C., 42
Crooked-guts, 237
Crookes' dark space, 265
Crookes, W., 265
Crossopterygii, 96, 101, 245*
Crustacean, an ancient, 71*
Cultures, 257, 259*
Cuvier, 86, 195, 265, 273, 286
Cyclostoma, 94, 243
Cynocephalus, 83
Cynodictis, 151
Cynodonts, 119
Cynognathus, 73*
Cynopithecus, 253*
Cytolysins, 232

D'ALEMBERT, 32
Dallinger, 203
Dapples, significance of, 114, 115, 158
Dart, R. A., 258
Darwin, Charles, 1, 35, 86, 146, 147, 164, 167, 259, 265, 269, 273, 278, 287, 288, 289
  statue of, *Frontispiece.*
Darwin, Erasmus, 266
Darwin, George, 35, 36, 45
Darwin's tubercle, 181*
Dasee. *See* Hyrax.
Dasyure, 158
Davison, D., 9
Dawn horse. *See* Eohippus.
Dawson, C., 290
Democritus, 260
Dendy, A., 63, 266
Dercum, F. X., 268
Descartes, 107
Desman, 251*
Development, 158
Devonian, 64, 69
Diana monkey, 132*
Didelphys, 250*
Difflugia, 153*
Digitigrade gait, 169, 176
Dimetrodon, 248*
Dimorphodon, 75*
Dinornis, 113
Dinosaurs, 65, 74, 76
Diplodocus, 65
Dipneusts, 94, 96, 101, 177, 245*, 246*
Dipnoi. *See* Dipneusts.
Dodo, 106
Dog-fish, 95*
Dog, foot of, 170*
Dogs, artificial selection of, 149*
Dolichosaurs, 108
Dolichosoma, 247*
Dolphin, brain of, 187*
Dominants, 278, 279
Down-nosed Monkeys, 128, 129*, 132, 253, 254*, 255*
Drosophila, 153
Dryopithecus, relationship to Man, 258*
Dubois, 83
Duck-mole, 74, 116*, 117
Duck-mole, brain of, 189*
Dwarf Mouse Lemur, 252*

EAR, bones of, 181, 183*, 184*
  muscles of, 223*
Ears, types of, 180*, 181*

Earth, the, 58*
  and moon, 35*
  comparative size of, 21*, 37*, 39*, 43*
  inclination to sun, 34*
  orbit of, 22*, 33*
  rotation of, 35*
  strata of, 63*
Echidna, 117, 249*
Echidnidæ, 116
Eclipse of sun and Einstein's prediction, 269
Ecology, 260
Eddington, A., 47, 51, 266–268
Edentata, 158
Eel, electric, 100, 101*
Eft, 101, 102*
Egg-cell, the, 206*, 208*, 213*, 234*
Egg-cell, human, 209*
Einstein, 167, 266–269, 276
Elasmobranchii, 94, 244*
Electric eel, 100, 101*
Electron, the, 56, 275, 280
  radius of, 268
Element, new, 55
Elimination of the unfit, 266
Elotherium, 81*
Embryo of animals, 218*, 219*
  of Man, 219*, 227*, 228*
  of shark, 244*
Embryology, 196
Emden, R., 47
Emergence, 281
Empedocles, 260
Endocrine organs, 107, 265
Energy, Conservation of, 46, 271, 274, 275, 277
  degradation of, 272
Energy, flux of, 281
Entellus, 132*
Enteropneust, 239*
Entropy, 272
Eoanthropus, 84, 285
  discovery of, 290
Eocene, 65, 78, 80
Eohippus, 8, 11, 65
  evolution of, 10*
  feet of, 11*
Epiblast, 214
Epicurus, 260
Epicycles, 262
Epigenesis, 260
Epihippus, 11, 12
  evolution of, 10*
Equinoxes, 34
Ergot, the, 171
Erinaceus, 123
Eros, 23
Ether, the, 276
Euclid, 259
Euglena, 204*
Eutheria, 115, 118
Evening Primrose, 288
Evolution, first idea of, 260
  meaning of, 1, 144, 164
Extinction, causes of, 114
Extra-galactic Nebulæ, 54

FAMILY TREE of Man, 9*, 257, 258*
"Fatigue" of metals, 264
Fayum apes, relationship to Man, 9*
Feathers, nature of, 109
Feet of Primates, 174*
Femaleness, 204
Fermentation, discovery of, 285
Fertilisation, 207*, 212
Finger of Man and horse, 171*
Fish, embryo of, 218*
  evolution of tail of, 161*, 162*
  gill-arches of, 216*
  primitive, 69*, 70*
Fishes, classification of, 94
  number of species of, 101
Flammarion, 26, 35, 39, 40, 51
Flat-nosed monkeys, 128, 129*, 252*, 253
Fleure, H. J., 269
Flower, W., 169, 171, 192
Flying-fish, 100*
Foot, bones of, 169*
  of Man, dog and horse, 170*
Fossils, Cambrian, 68*
Fourth Dimension, 269
Frog, development of, 102*, 103

GALACTIC NEBULÆ, 54
  System, 51
Galeopithecus, 123*, 124
Galileo, 259
  persecution of, 261
Galla native, 140*
Galton on heritage, 269

Gametogenesis, 210*
Ganoids, 96, 97, 245*
Gastræa theory, 271
Gastræad, 88*, 236*
Gastrophysema, 213*, 235*
Gastrotricha, 238*
Gastrula, 88*, 235*, 271
Gastrulation, 213*, 214
Geddes, P., 206, 270, 288
Geddes and Thomson, 206, 207, 211
Gegenbaur, 178, 179, 270
Genealogical tree of mammals, 9*
  Primates, 258*
Generalized and specialized organs, 142
Genesis, 66
Geological strata, 63*, 259*
  time-scale, 63*, 167*
Germ-cell evolution, 283, 284
  plasm, continuity of, 289
Germ layers, 263
Giants' Causeway, 60, 61*
Gibbon ape, 133*, 134, 255*
  brain of, 188*
Gill-arches, 183, 215*
  of bird, 216*
  of fish, 216*
  of mammal, 216*
Giraffe, brain of, 187*
Glacial periods, 66, 259*
Globular clusters, 50
Gnathostoma, 243
Goethe as an evolutionist, 270
Gorilla, 134*, 135*, 136
  and Man, 150*
  brain of, 188*
  hand of, 179*
Gravitation, 267, 268
  law of, 262
Gravitational instability, 39
Gregory, J. W., 270
Gregory, R., 270
Günz Glacial, 259*

h. 3433, 268
Haeckel, 92, 158, 165, 270, 271
Hæmatococcus, 201, 202*
Hag-fish, 243
Hair, disposition of, 181, 182*
Hairs and scales, 158
Half-apes, 253
Half-lop rabbit, 156*
Hammer-headed shark, 94*
Hammurabi, 45
Hand of Amphibian, 179*
  gorilla, 179*
  man, 179*
  whale and Man, 177*
Hands of Primates, 173*
Harvey, 260, 271
Hatteria. *See* Sphenodon.
Heat and work, 274
Heat-death of Universe, 56, 272, 281
Hector, 23
Helium, origin of, 280
Helmholtz, 45, 271, 274, 275
Heraclitus, 259, 260
Hercules, star-cluster in, 51*
Heredity, 207, 289
  laws of, 144, 269
  principles of, 278, 279
Herring, 120*
Herschel, Caroline, 33
Herschel, William, 32, 33
Hesperornis, 78*, 164
Heterocercal tail, 161, 162*
Heteromita, 203*
Hipparchus, 259, 261
Hipparion, 13, 82*, 217
  evolution of, 10*
  feet of, 12*
Hippidion, 13
  evolution of, 10*
Hippocampus Minor, 192*
Hirn, M., 275
Hoatzin, 194*, 195*
Hog, embryo of, 219*
Holism, 286
Holmes, A., 62, 63, 165
Holocephali, 96
Homer, 259
Homo Sapiens, 167
  Sinanthropus, 84*, 285
Homocercal tail, 161*
Homologous organs, 112
Hooker, Joseph, 271, 272
Hoolock, 133*
Hormones, 107, 265
Hornaday, Dr., 141
Hornbill, 266
Horse and Man, 168*, 171*, 172*
Horse, evolution of, 8, 10*, 15
  foot of, 12*, 170*
  two-fingered, 14*, 15*

Hottentot, 140*
Howler Monkey, 252*
Hudgings, W. F., 276
Human fœtus, Appendix of, 222*
  ovum, 209*
Humboldt, 131
Huxley, J., 271
Huxley, L., 271
Huxley, T. H., 192, 193, 271, 272, 288
Hydrogen, synthesis of, 280
Hylobates, 255*
Hypoblast, 214
Hypohippus, 13
  evolution of, 10*
Hypothesis, 33
Hyracotherium, 11, 78, 79*
  evolution of, 10*
Hyrax, 16, 17*

ICHTHYORNIS, 77*
Ichthyosaurs, 65, 74
Ichthyosaurus, 107*, 108, 109
  third eye of, 108*
Incus, 181
Indeterminism, 272, 286
Indris, 125
Inertia, 267
Infant supporting its own weight, 220*
Inge, Dean, 85
Insect-eaters, 122*
Insectivora, 122*, 124, 251
Insects, number of species, 101
Insulin, 107
Intensity factor of energy, 274
Invertebrates, 89
Irish Elk, 266
Irritability, 230, 264

JEANS, J., 25, 26, 27*, 31, 39, 45, 46, 47, 48, 49, 51, 52, 54, 55, 56, 268, 272, 281
Joe Martin, 139*, 140
Jordan, D. S., 273
Joule, 274
Juno, 23
Jupiter, 24*, 25
  comparative size of, 21*, 37*, 39*
  moons, of, 24*, 25
  orbit of, 20*
Jurassic, 74

KANGAROO, brain of, 189*
Kant, 32, 33, 34
Katabolism, 204
Kathodal glow, 265
Keith, Arthur, 83, 84, 127, 137, 193, 258, 259, 266, 273
Kelvin, 45, 272, 281
Kepler, 262
Keraterpeton, 247*
Kiang, 15
  evolution of, 10*
King Crab, 233
Kiwi, 112*, 113
Künsleria, 88*

LAGOTHRIX, 132
Lamarck, 86, 259, 266, 273
Lamprey, 93*, 94, 243
  larva of, 242*
Lancelet. *See* Amphioxus.
Lankester, Ray, 107, 108, 194, 274
Laplace, 32,* 33
Larval organ, 118
Lavoisier, 274, 275
Law, 2
  of Conservation of Energy, 274, 277
  of Conservation of Mass, 274
  of Conservation of Matter, 46
  of Filial Regression, 269
  of Heredity, 144, 269
  of Over-production, 146
  of Variation, 144
  periodic, 279
Laws of Planetary Motions, 262
Le Conte, 161
Le Sage's theory of gravitation, 267, 268
Lemaitre, G., 266
Lemur, 125*, 252*, 253
Lemuroidea, 125, 126
Lemurs, relationship to Man, 9*, 258*
Lepidosiren, 96, 97*
Leptothrix, 198*
Leucocytes, 205*
Leverrier, 28
Lice, 153
Life, origin of, 281, 284
  Sir Oliver Lodge on, 276, 277
Light, deflection of, by matter, 266, 269

Limb buds, 178
Limbs, evolution of, 177, 178, 179, 230, 231
  of Man and quadrupeds, 175*, 176*
Limulus, 233
Links, connecting, 85
Linnæus, 125, 213, 276
Lion, brain of, 187*
Lip ornaments, 141*
Lister, 285
Lockyer, 276
Lodge, Oliver, 276, 277
Loeb, Jacques, 277
Loeury, 30
London Man, relationship to modern Man, 258*
Loris, 128*
Lowell, P., 28
Loxomma, 247*
Lucretius, 259, 260
Lull, R. S., 8, 10, 277
Luminosity related to mass, 267
Lumpsucker, 97, 98*
Lunate bone, 175
Lung-fish, 64, 97*, 165
Luther ridicules Copernicus, 261
Lyell, 86*, 272, 286

" M. 13," 51*
" M. 31," 268
" M. 33," 268
" M. 83," 268
Macacus, 83
Macallum, 282
MacBride, 124, 133
Machærodus, 266
Macrococci, 198*
Magdalenian culture, 259*
Magnetic storms, 41
Magnitude, stellar, 29
Magosphæra, 235*
Maleness, 204
Malleus, 181
Malthus, 289
Mammal, gill-arches of, 216*
Mammals, 114, 115
  origin of, 166, 251
Man and gorilla, 150*
  and horse, 168*, 171*, 172*
  and quadrupeds, limbs of, 175*, 176*
  and whale, hand of, 177*
Man, appendix of, 222*
  brain of, 188*
  early ancestor of, 251
  embryo of, 219*, 227* 228*
  family tree of, 9*, 257, 258*
  foot of, 170*
  hand of, 179*
  of the woods, 254*
  origin of, 127
  tail of, 227*, 228*
Man-like monkeys, 129*
Marmosets, 129*, 130
Mars, orbit of, 22*
  comparative size of, 21*, 37*, 39*
Marsh, 8
Marsupials, 117, 119, 251
Mason, Frances, 256
Mass, 275
  Conservation of, 274, 275
  related to luminosity, 267
Mastodon, 65, 81*
Materialism, precursor of, 260
Mathematics and the Cosmos, 268, 269
Matter, 275
  and energy, 46, 47
  conservation of, 46
  flux of, 281
  synthesis of, 280
Matthew, 8, 265
May Browne, 140
Mayer, 274, 275, 277
McBride, E. W., 277
McCabe, Joseph, 277
Mechanical equivalent of heat, 274
Megalosaurus, 74, 75*
Meiosis, 210*, 211
Melanchthon, 261
Mendel, 269, 278
Mendeléef, 279
Mercury, comparative size of, 21*, 37*, 39*
  orbit of, 22*
  shift of perihelion of, 267
Merychippus, 13
  evolution of, 10*
Mesoblast, 214
Mesohippus, 12, 65
  evolution of, 10*
  feet of, 12*
Mesopithecus, 83*

Mesozoic. *See* Secondary.
Metals, " fatigue " and " poisoning" of, 264
Metamorphic rocks, 62
Metatheria, 115, 118, 158
Metazoa, ancestry of, 271
Metchnikoff, 280
Meteorite, 49, 50*
Meteors, 49
Meyer, 279
Microcebus, 252*
Micrococci, 198*
Micro-organisms, 199
Midas, 185
Millikan, R. A., 57, 280, 281
Mindel glacial, 259*
Mind, Sir Oliver Lodge on the, 276, 277
Miocene, 65, 81
Miohippus, 12, 65
  evolution of, 10*
  feet of, 12*
Missing links, 9*
Mitchell, Chalmers, 281
Moa, 113
Moeritherium, 81
Mole, related to shrew, 251
Momentum in evolution, 266
Monera, 233
Monkey and young, 256*
Monotremata, 116, 117, 118, 251
Moon, 29, 30*
  and Earth, 35*
  comparative size of, 39*
  orbit of compared to sun's equator, 43*
Moons of Jupiter, 24*, 25
Moræad, 233, 234*
Morgan, Lloyd, 281
Morphology, 270
Morula, 234*. *See also* Moræad.
Mosasaurs, 65, 108
Moulton, 37
Mousterian culture, 259*
Mud-fish, 96, 97*
Multituberculata, 119, 251
Muscles, vestigial, 223*
Musk-shrew, 251*
Mutation, 288
Myogale, 251*
Myrmecobius, 157*
Myxomycetes, 206*

NATURAL Selection, 1, 101, 147, 148, 164
Neanderthal Man, relationship to modern Man, 258*
Neanderthal race, 84
Neanderthaloids, 127
  relationship to Man, 258*
Nebula, 33, 38*, 52*
  in Andromeda, 55, 56*
  in Orion, 54*
Nebulæ, distance of, 55
  mass of, 55
  number of, 54
  size of, 54
Nebular hypothesis, 32, 36
Nebulium, 54
Nemertine worm, 239*
Neo-ceratodus, 96, 97*
Neolithic culture, 259*
  Man, relationship to modern Man, 258*
Neopallium, 285
Neopithecus, relationship to Man, 258*
Neptune, 28
  comparative size, 21*, 37*, 39*
  orbit of, 20*
Nerve-cord, 241*
Nervous system, origin of, 230
Neutrons, 56
Newlands, 279
Newt, 101, 102*
Newton, 258, 259, 260, 262, 269
New-World Monkeys, relationship to Man, 258*
N.g.c., 1499, 52*
N.g.c., 6992, 53*
Nictitating membrane, 221*, 222
Niton, 55
Notochord, 90, 230, 241*, 243
Nuttall, 232

Œnothera lamarckiana, 288
Oestrin, 107
Oken, 281, 282
Old-world Monkeys, relationship to Man, 258*
Oligocene, 65, 80
Omega Centauri, 51
Onohippidion, 13
  evolution of, 10*
Ontogenesis, 159, 160, 161, 271
Ontogeny. *See* Ontogenesis.

Oocytes, 211, 212
Oogenesis, 210*
Oogonia, 211
Opisthocomus,. *See* Hoatzin.
Opossum, 250*
Orang-utan, 137*, 254*
  appendix of, 222*
  brain of, 188*
  ear of, 181*
Ordovician, 64
Origin of life, 281, 284
  of species, 1, 265
Ornithopoda, 76
Ornithorhynchidæ, 116
Ornithorhynchus, 74, 116*, 117
  brain of, 189*
Orohippus, 11
  evolution of, 10*
  feet of, 12*
Osborn, H. F., 68, 281
Ouakari, 130*, 131
Ova, 206*, 208*, 209*, 213*, 234*
Ovary, 107
Over-production, Law of, 146
Over-specialization, 114
Ovum, first discovery of, 263
  human, 209*
  See also Ova.
Owen, R., 282

PALÆOMASTODON, 81
Palingenesis, 159, 271
Pallas, 23
Paludina, 85*
Pancreas, 107
Pangolin, 158*
Papish, Prof., 55
Parahippus, 13
  evolution of, 10*
Parental love, 256*
Pariasaurus, 72*, 248*
Parietal eye, 108*
Parker, 204, 205
Parsec, 31
Pasteur, 285
Pavlov, 282
Peake, H., 269
Pearson, Karl, 270, 282
Pei, W. C., 285
Peking Man, 84*, 127, 285
  relationship to modern Man, 258*
Pemmatodiscus, 88
Pen-tailed Tree Shrew, 250*
Periodic Law, 279
Periophthalmus, 99*, 100
Perissodactyles, 169, 171
Permian, 64, 71
Phagocytosis, discovery of, 280
Phalanger, 249*
Phylogenesis, 159, 160, 161, 163, 271
Phylogeny. *See* Phylogenesis.
Piano, evolution of, 6, 7*
Pig, effect of artificial selection on, 148*
Pigeons, varieties of, 144*
Piltdown Man, 127, 285
  discovery of, 290
  relationship to modern Man, 258*
  skull of, 84
Pineal eye. *See* Pineal organ.
Pineal organ, 105*, 106*, 107
Pipe-fish, 98*, 99
Pisces, 94. *See also* Fish.
Pithecanthropus, 83, 84*, 127, 166, 195, 285
  relationship to Man, 9*, 258*
  skull of, 193*
Pituitary organ, 107
Pituitrin, 107
Placenta, 133
Placentalia, 119
Plagiaulacidæ, 251
Planck, 167, 286
Planetary Laws, 262
  Nebulæ, 53
Planetesimal theory, 38
Planets, distances of, 29
  masses of, 39*
  minor. *See* Asteroids.
  orbits of, 22*
  origin of, 272
  sizes of, 21*, 37*
Plant cell, 197*
Plantigrade gait, 169, 176
Planula, 88
Plated fishes, 245*
Platodaria, 236*
Platodes, 236
Platypus. *See* Duck-mole.
Platyrrhines, 128, 129*, 252*, 253
Pleistocene, 66, 82

Plesiosaurs, 65, 74, 108
Pliocene, 65, 82
  apes, 83
Pliohippus, 13
  evolution of, 10*
  feet of, 12*
Pliopithecus, relationship to Man, 258*
Pluto, 22, 40, 44
  comparative size of, 21, 37*
  discovery of, 28
  orbit of, 20*
Poincaré, H., 2
Poisons, evolution against, 283, 284
Polar bodies, 207*, 210*, 212
Polypterus, 96, 97*, 245*
Pony, ancestral stripes in, 156*
Porto Santo Rabbit, 153
Poulton, E. B., 282
Pre-Cambrian rocks, 67
  sea, salt in, 283
Prehistoric cultures, 259*
Premaxilla, 270
Primary Era, 64
Primates, 124, 126
  classification of, 125
  feet of, 174*
  first appearance of, 166
  hands of, 173*
  skeletons of, 138*
Prochordonia, 240, 241, 243
Promammals, 248
Prominences, solar, 41, 42*, 43*
Propliopithecus, relationship to Man, 258*
Proreptilia, 104, 106
Prosauria. *See* Proreptilia.
Protococcus, 201, 202*
Protodonts, 119
Protohippus, 13
  evolution of, 10*
  feet of, 12*
Protomyxa, 206*
Protons, 56, 275, 280
Protoplasm, 198
Protopterus, 96, 97*
Prototheria, 115, 118
Proxima Centauri, 31
Pseudopodia, 200*
Pterodactyle, limb of, 110*
Pterosaurs, 65, 74, 108, 113
Ptolemy, 259, 261
Puisseux, 30
Pycraft, W. P., 194, 282
Pygostyle, 163*
Pythagoras, 268
Python, hind legs of, 226*, 227

QUADRUMANA, 175
Quagga, 14
  evolution of, 10*
Quanta, 275
Quantum theory, 286
Quaternary, 66
Quinton, R., 282, 284

RABBIT, embryo of, 219*
  fish, 96*
  half-lop, 156*
  Porto Santo, 153
Radiation pressure, 263
Radiations, 45, 56, 275
  Cosmic, 280
Radium, 55
Ramphorhyncus, 109*, 110
Recent age, 66
Recessives, 278, 279
Reducing process in Conjugation, 210*, 211
Reid, Archdall, 283
Relationship, meaning of, 86
Relativity, 267, 268
Reproduction, nature of, 229, 230
Reptiles, 103
  early, 247, 248*
  first appearance, 166
Reversion, 157, 260
Rhabdocœlum, 237*
Rhodesian Man, 127
  relationship to modern Man, 258*
Rhopalura, 88*
Rifle, evolution of, 6, 7, 8*
Ring Nebula, 55*
Ring-tailed Lemur, 125*, 126
Ritchey, Prof., 56
Robinson, L., 220, 222
Rock Wallaby, 118*
Romanes, 148, 284
Rorqual, 120*
Rudimentary limbs, 225*, 226*
Rudiments, 179, 217
Ruminants, 161

Russell, Bertrand, 262
Rutherford, Lord, 265, 284

SAGE's (LE), theory of gravitation, 267, 268
Sagitta, 213*
Saki, 130*, 131
Salamander, embryo of, 218*
Saleeby, C., 196, 284
Salt in evolution, 282, 283
Saturn, 26*
  comparative size of, 21*, 37*, 39*
  orbit of, 20*
Scaphoid, 175
Schäfer. *See* Sharpey.
Schleiden, 284, 285
Schwann, 284, 285
S. Doradus, 45
Sea-horse, 98*, 99
Sea-squirt, 90, 91*, 92*
Seal, brain of, 187*
  skeleton of, 224*
Secondary period, 64
Segmentation, 213*
  cavity, 214
Selachii, 177
Selection in Evolution, 287. *See also* "Artificial" and "Natural."
Semnopithecus, 83
Shapley, 50
Shark, 243, 244*
  limb of, 177*
  primitive, 70*
Sharpey-Schafer, E., 284
Sherrington, 285
Shipley, 124, 133, 285
Shooting-star. *See* Meteors.
Shrew, 122, 123*, 250*, 251*
Silurian, 64, 68
  Molluscs, 69*
Simia Satyrus, 137*, 254*
Simiidæ, 83, 132, 133, 134
Siriometer, 31
Sitter, de, 266
Sivalik apes, relationship to Man, 9*
Skate, 95*
Skeleton of Man and gorilla, 150*
  Primates, 138*
  seal, 224*
  whale, 225*
Skull, Oken on the, 281
Skulls of Man and apes, 84*, 193*
  and horse, 172*
  and monkey, 131*
Slime theory, 281
Smith, Elliot, 83, 127, 193, 285
Smith, W., 62, 286
Smuts, J., 286
Snout-worm, 239*
Socrates, 259
Soddy, F., 265, 286
Solar System, 20*, 40
Sollas, 286
Solomon, 259
Solstices, 34
Solutrean culture, 259*
Sorex, 122
Space, 269
Space-time, 286
Species, definition of, 153
  Linnæus on, 276
  mutability of, 164
  number of, 101
Spectrum, 53
Spencer, 152, 266, 284, 287
Spermatids, 211, 212
Spermatocytes, 211, 212
Spermatogenesis, 210*
Spermatogonia, 211
Spermatozoon, 206*
Sphenodon, 104*, 105, 106, 107
  third eye of, 105*
Spider-monkey, 130*, 131
Spinal cord, 90
Spiral nebula, 38*
Spirillum, 198*
Spiritualism, 276
Spirochæte, 198*
Sponge, ovum of, 234*
Springing Monad, 203*
Squirrel-monkey, 130*, 131
Stapes, 183
Stars, number of, 51, 53
Stegocephala, 71, 103, 177, 247
Stieda's organ, 107
Stinking Pheasant. *See* Hoatzin.
Straight-guts, 237
Strata, 59, 64
  thickness of, 62, 63*
Stratified rocks, 59*, 60*
Streptococci, 198*
Struggle for existence, 146, 147

Sun and Planets, 37*, 39*
  energy of, 47
  heat of, 43, 46, 47, 48
  loss of weight of, 44*, 45
  mass of, 39*
  shrinkage of, 44*
  size of, 39*, 43*, 44*
  temperature of, 267*
Sunspots, 40*, 41*
Survival of Fittest, 6, 147, 260, 287, 289
Swammerdam, 287
Sylvian fissure, 185

TABLE of strata, 63*
Tadpole, 92*
Tail, evolution of, 161, 162, 163, 164
  of Man, 227*, 228*
Tailed apes, 132*
Talpa, 123
Tapir, 16*
Tarpan, 15
  evolution of, 10*
Tarsiodea, 127
  relationship to Man, 9*
Tarsipes rostratus, 249*
Tarsius, 9*, 126*, 127*
  relationship to Man, 9*
Taungs Man, relationship to modern Man, 9*, 258*
Taxonomy, 153
Tcheli, 132*
Tears, significance of salt in, 283
Teleostomi, 94, 96
Teleosts, 65, 96
Tennyson, anticipates Darwin, 287
Tertiary, 65, 77
Thales, 259, 260
Thallium, discovery of, 265
Themis, 26
Theromorpha, 72, 73*, 103, 108, 168, 248
Theropoda, 76
Third eye, 105, 106, 107
Third eyelid, 221*, 222
Thomson, A., 206, 207, 211, 228, 270, 287
Thomson, J. J., 265, 288
Thooid, 151
Thresher shark, 94*
Throw-back, 157, 260
Thyroid gland, 107
Thyroxin, 107
Tidal disruption, 38, 39
  friction, 36
Time, 269
  in evolution, 165
Tinoceras, 79*, 80
Tombaugh, C., 28
Tortoise, embryo of, 218*
Trachodon, 76
Tradescantia, 197*, 198
Transition stages, 230, 231
Transmission of acquired characters, 266
Tree-shrew, 250*
Triassic, 65, 72
Triceratops, 76*
Triconodonts, 119
Trilobites, 64, 67*, 68
Trilophodon, 81
Trituberculata, 119
Tuatara. *See* Sphenodon.
Tunicates. *See* Ascidians.
Turbellarians, 236, 237*
Turner, Prof., 36
Tyndall, 288
Tyrannosaurus, 76

UNGULATES, 16
  divisions of, 169
Universe, the, 19
  conception of, 268, 269, 272, 286
  diameter of known, 267
  expanding, 266, 267
  materials of, 56
Unstratified rocks, 60*
Uranus, 28
  comparative size of, 21*, 37*, 39*
  orbit of, 29*
Uraster, 213*
Ur-schleim, 281
Use and disuse, 273

VARIATION, 143, 144, 146
  Law of, 144
Varieties, 153
Veddah, 6*
Venus, comparative size of, 21*, 37*, 39*
  orbit of, 22*
Vermalia, 238*

Vermes, 238
Vermiform appendix, 222*, 223
Vertebræ, 93*
Vertebrated tail-fin, 162*
Vertebrates, characteristics of, 243
  origin of, 231
Vespertilionidæ, 122
Vestiges, 179
Vestigial actions, 217, 220
Vibrio, 198*
Virchow, 285
Virginian spider-wort, 197*, 198
Vitalism, 284
Vries, de, 288

WALLACE, 1, 167, 265, 288
Warmetod, 272
Watson, D., 289
Weasel-ape, 123*
Weight, 267
Weismann, 289
Wells, H. G., 289
Wells, W. C., anticipates Darwin and Wallace, 265
Whale, 120*
  and Man, hand of, 177*
  hind-limbs of, 225*, 226
  origin of, 233
Whalebone, 121
Wheeler, W. M., 289
Whipsnade, Zoo at, 281
White blood corpuscles, function of, 280
Wiedersheim, 105, 289, 290
Wilberforce, 86
Wilson, W. E., 53
Wing of Hoatzin, 195*
Wings, origin of insect, 270
  structure of, 110*
Wood-Jones, 127
Woodward, Smith, 84, 290
Woolly monkey, 132
Work and energy, 275
  and heat, 274
Worms, 238*
Würm glacial, 259*

YEAST-CELLS, 197*
Young, 43

ZEBRA, 14
  evolution of, 10*
Zoo, Whipsnade, 281
Zygote, 210*, 211, 213